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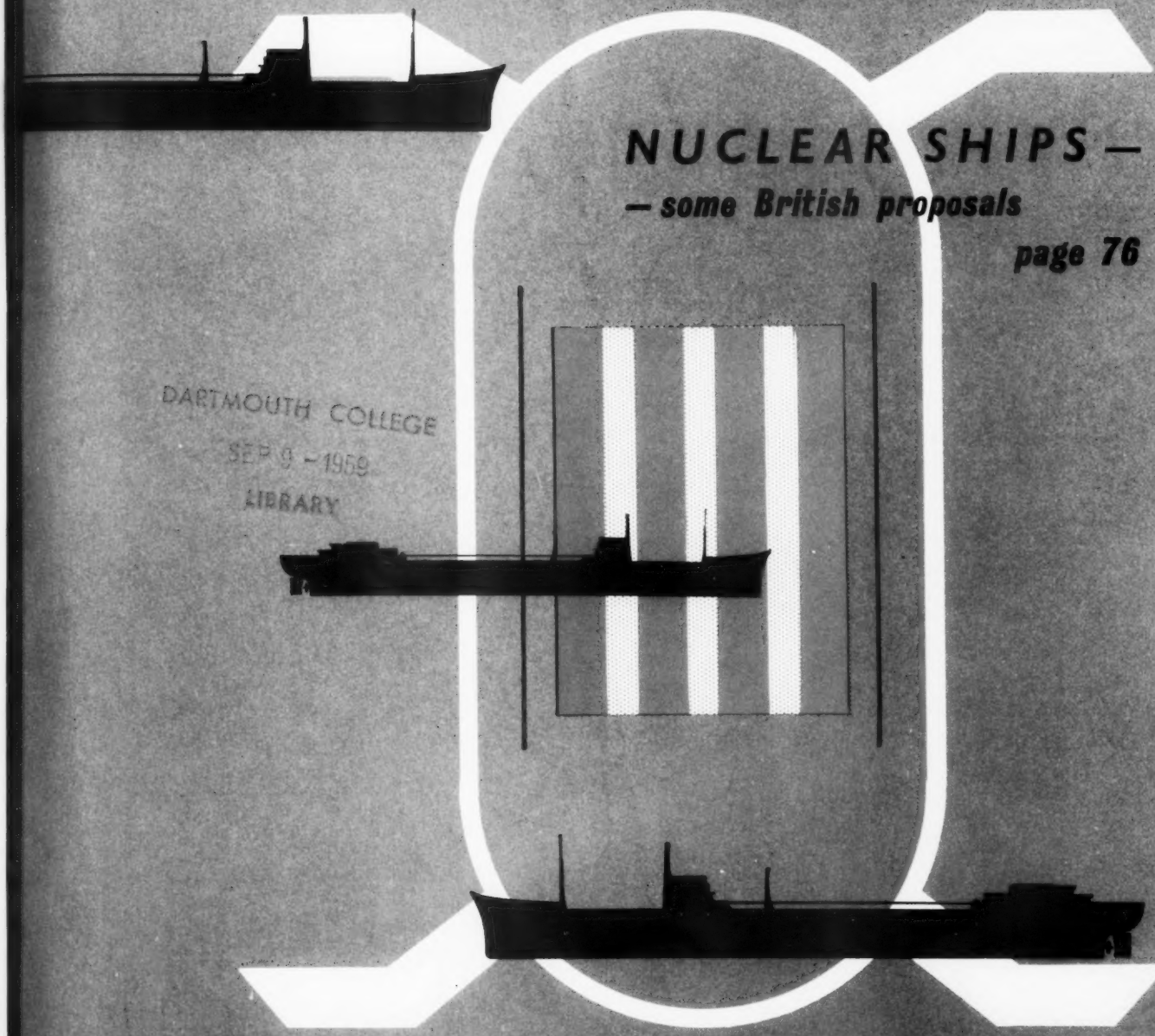

NUCLEAR SHIPS —

— some British proposals

page 76

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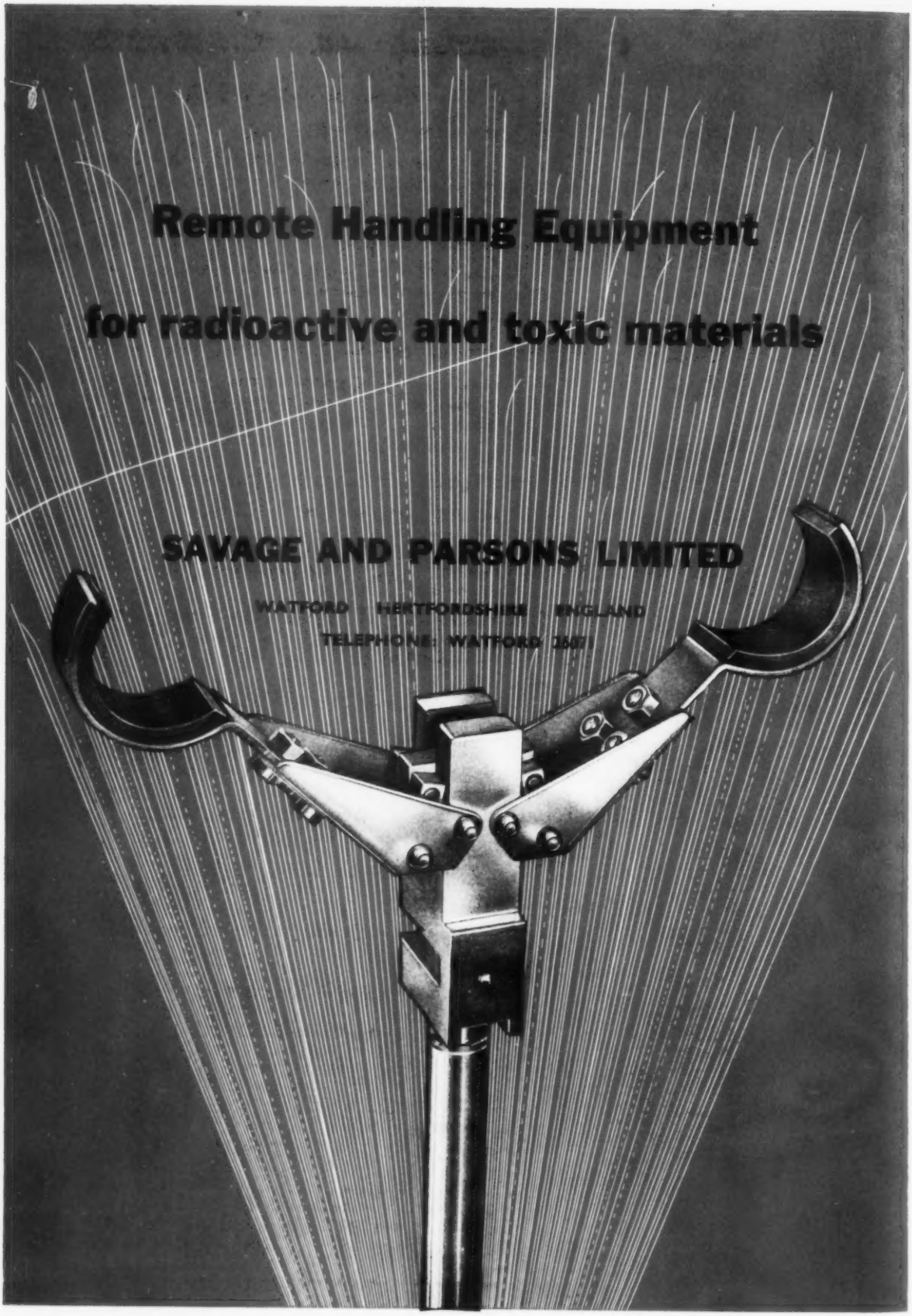

Nuclear Power

REACTORS · MATERIALS · INSTRUMENTATION · PROCESSES · RADIATION

VOL 4 NO 40 AUGUST 1959

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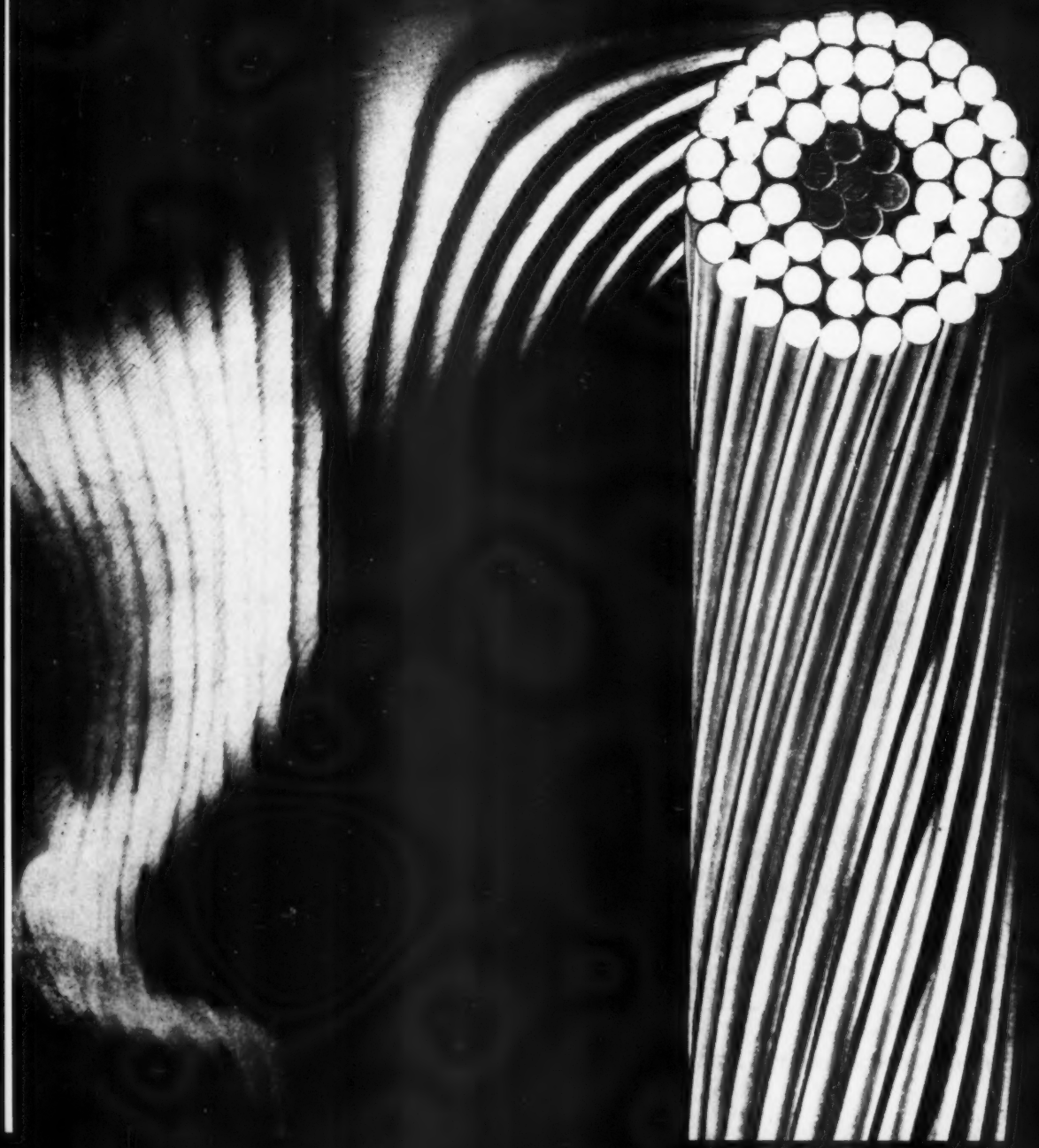
Shell Ensis 356 – years of



protection for the grid

The great web of overhead lines which covers this country, the thousands of miles of conductors that stretch out over factory chimneys, along the sea shores, over rivers and estuaries, sets a particularly difficult corrosion problem. Everywhere there is a tendency for the protectives to drain away down the sagging curve of the lines, leaving the sections near the insulators bare. Every day these unprotected sections are attacked by the acid fumes of industrial areas, the mist and wind-borne salt from the sea.

Here was a problem, indeed; to produce a protective which would be liquid enough to apply in manufacture, and yet on cooling would remain plastic and solid enough to resist the tendency to drain away under the heat of the summer sun.

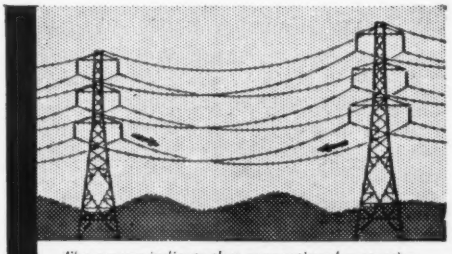
Shell spent many years examining these apparently contradictory requirements. Finally they produced Shell Ensis Compound 356. A measure of the success of their research is that 356 will add years to the life of s.c.a. conductors. Because of its unique qualities it was applied in the manufacture of the 2½ mile transmission cables spanning the estuaries of the Rivers Severn and Wye, one of the highest and longest river crossings in the world.

The research that went into 356 is characteristic of the way Shell set about doing things. It was developed at Shell's Research Centre at Thornton, and is the end product of a long line of protective greases. In its experimental form 356 was already being used by important manufacturers supplying the Central Electricity Generating Board.

The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors to produce the right protective for the job. If you and your organization have any major lubricating problems, it pays to get in touch with Shell.

The Research Story

Special tests had to be developed to determine whether each of the many formulations examined would liquefy easily at critical temperatures and re-solidify without separation or change. At the same time the resistance to drainage at temperatures likely to be reached in summer had to be assessed. Steel plates dipped under controlled time and temperature conditions in the liquefied protective were held in temperature controlled ovens for 24 hours, the weight of material drained was then measured. Formula after formula was tried and rejected, until one which gave a negligible drainage rate was finally arrived at.



The arrows indicate that conventional protectives flow towards the sag point. This leaves the areas nearer the pylons unprotected.

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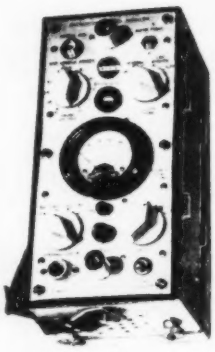

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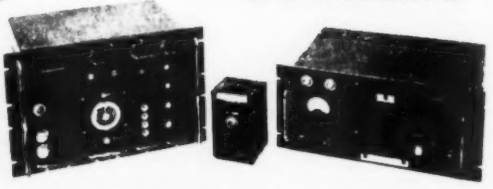

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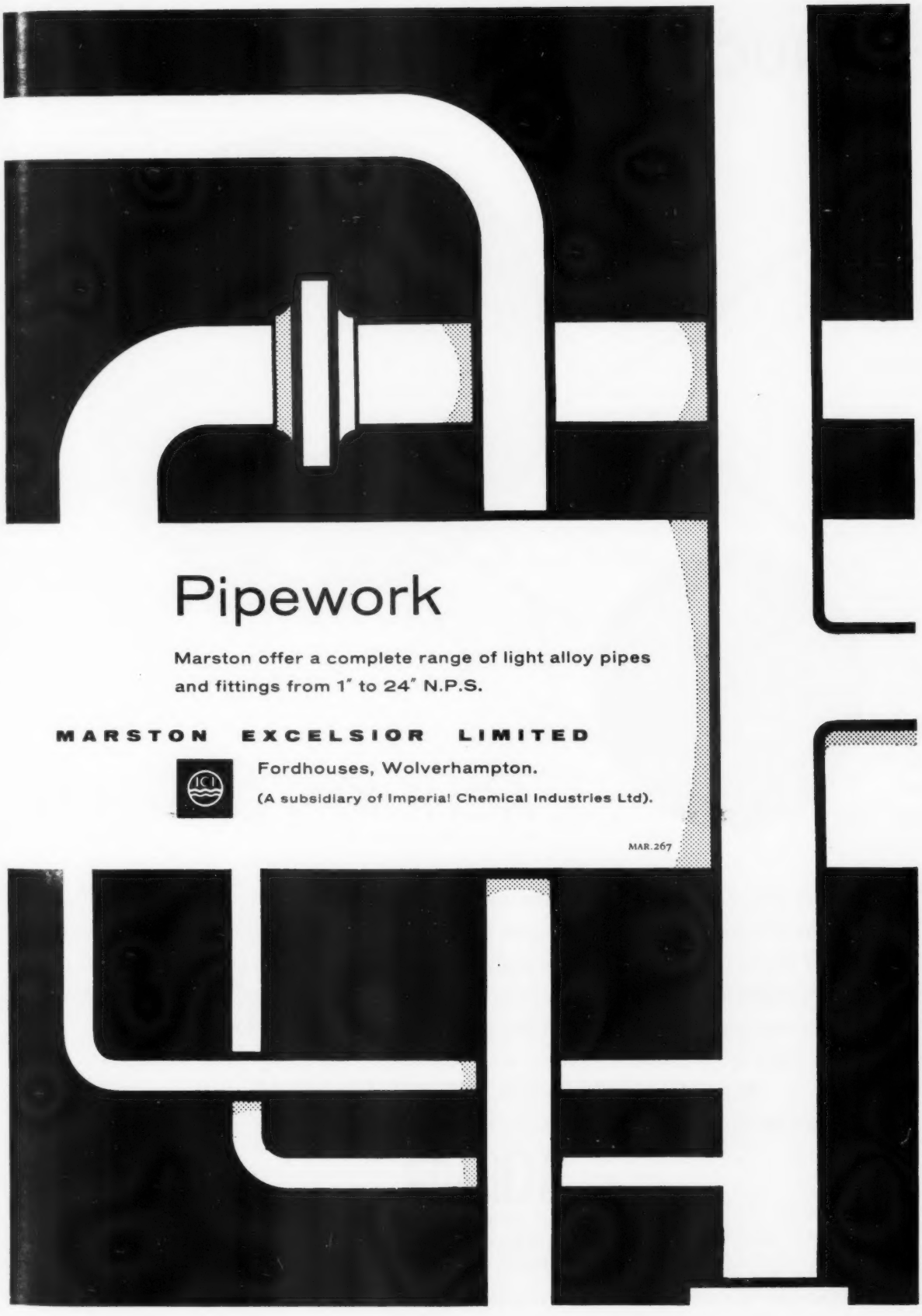

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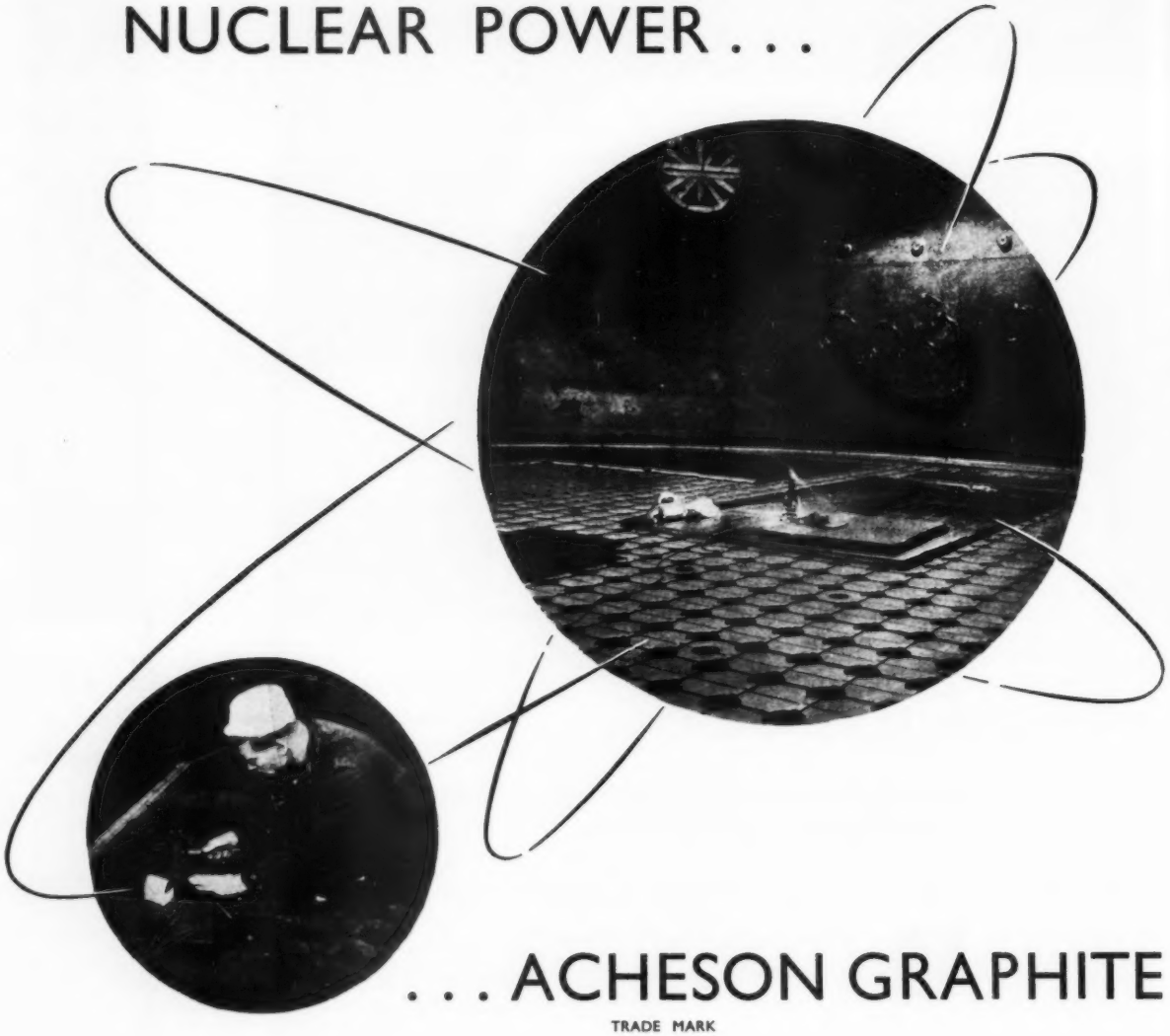

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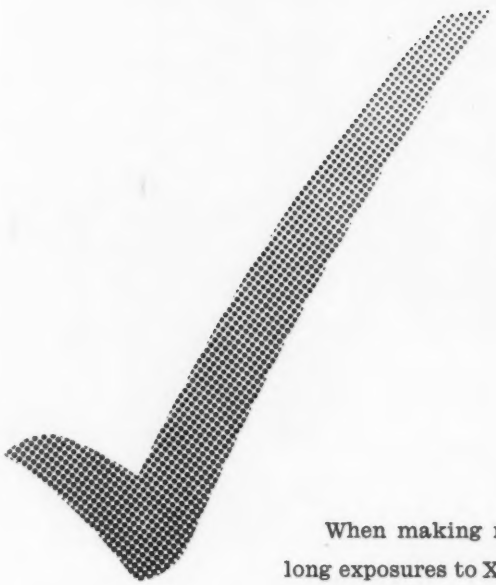

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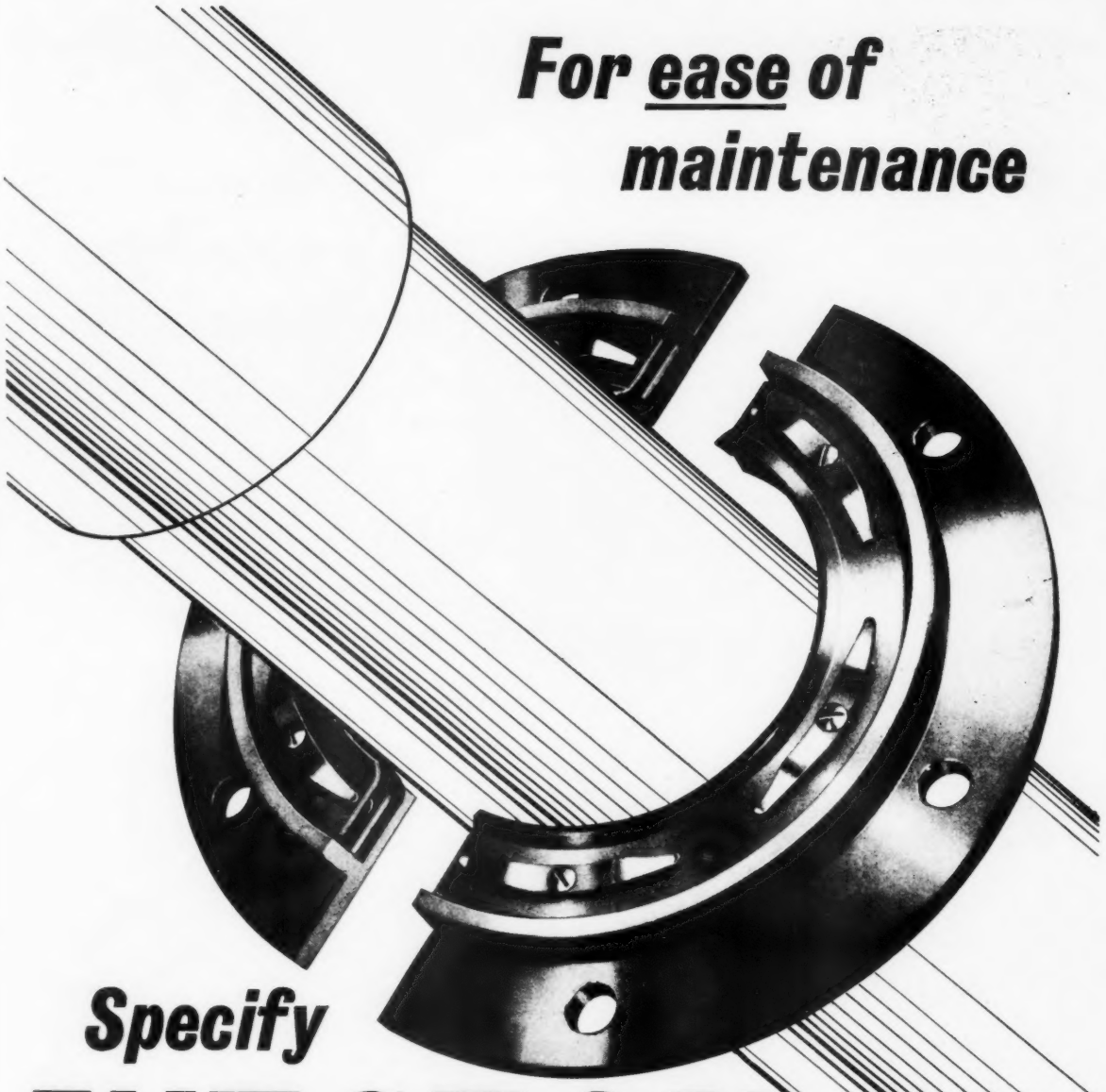

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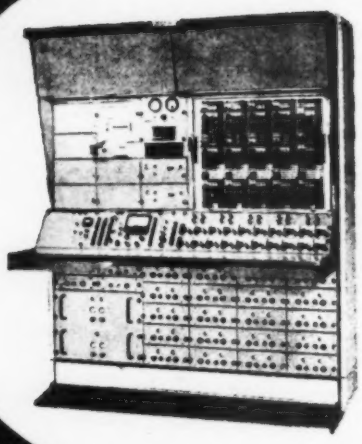

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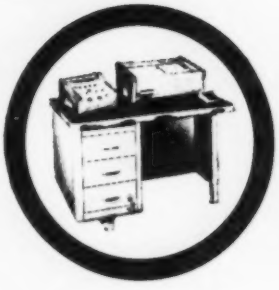

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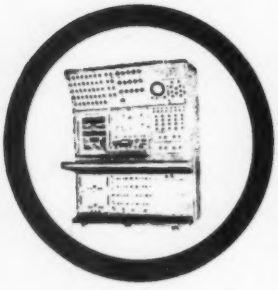

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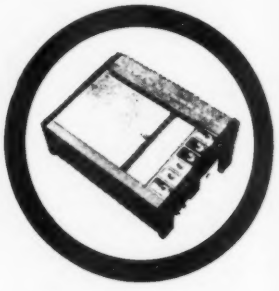

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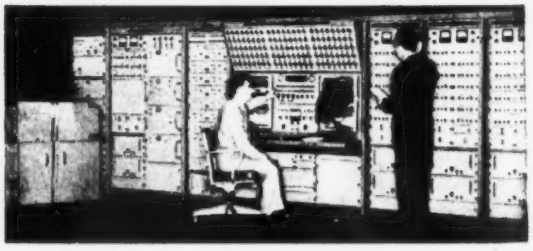

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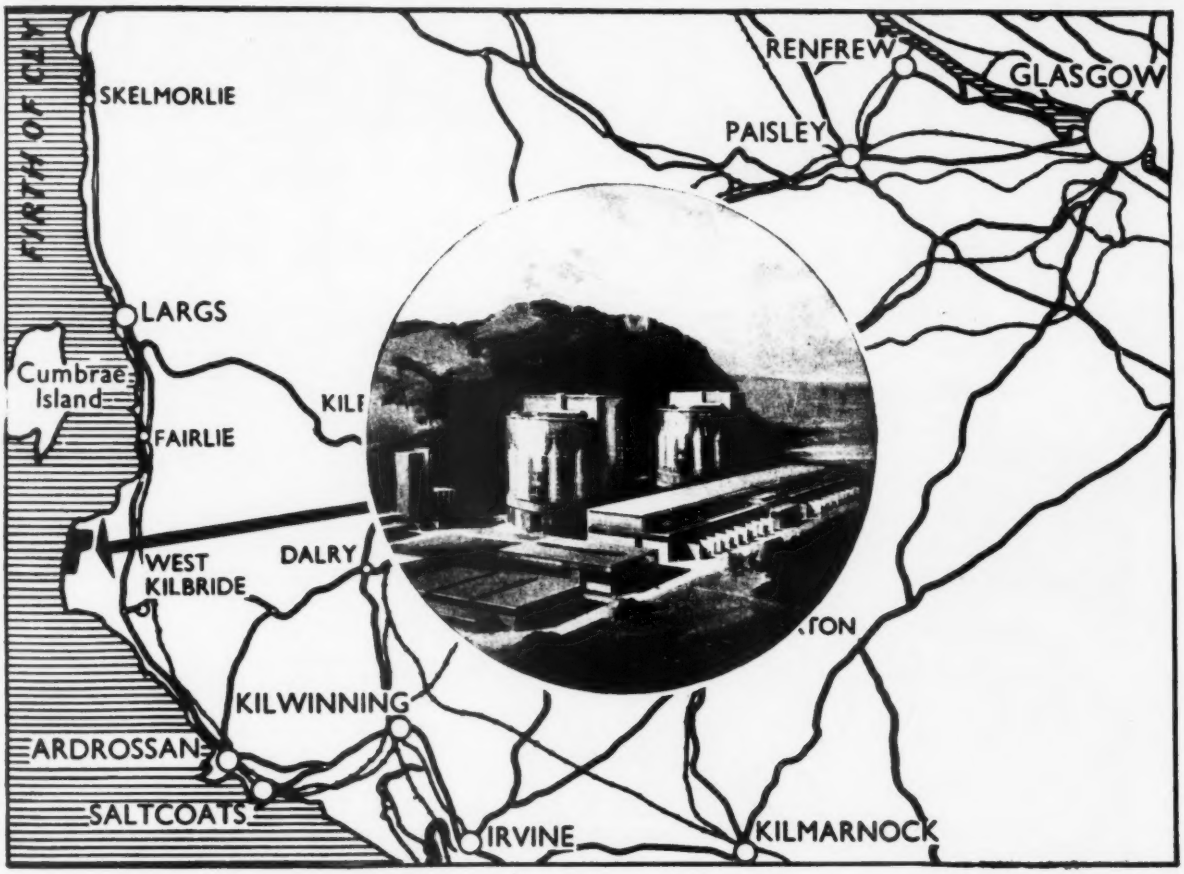

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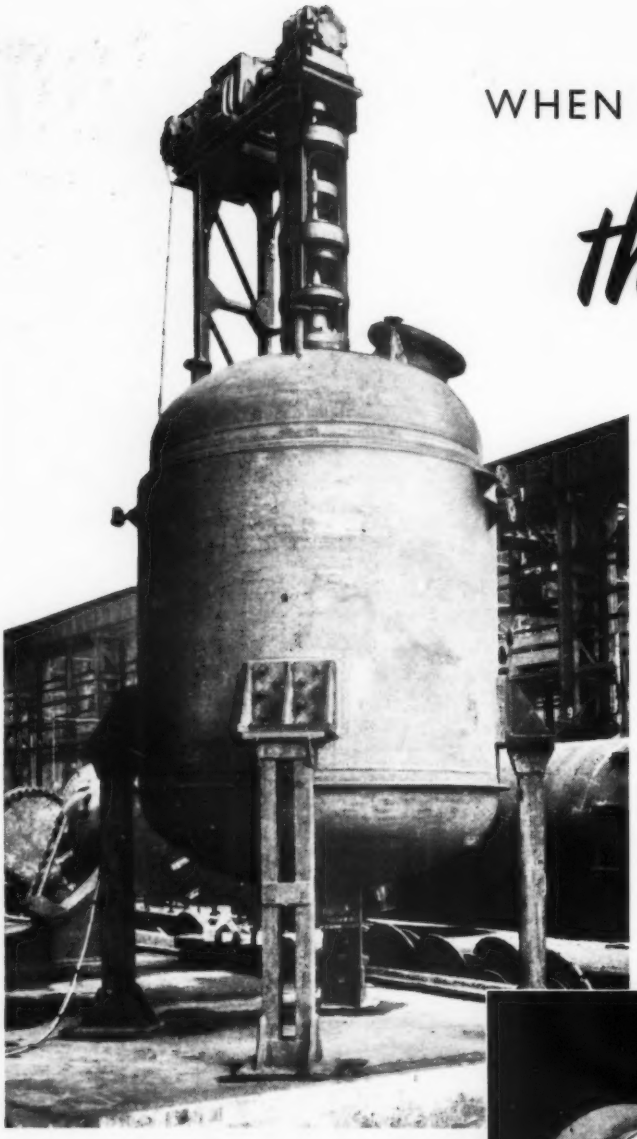

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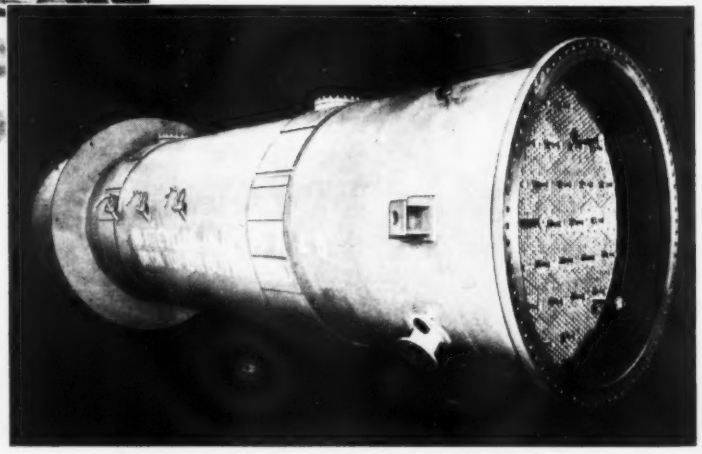

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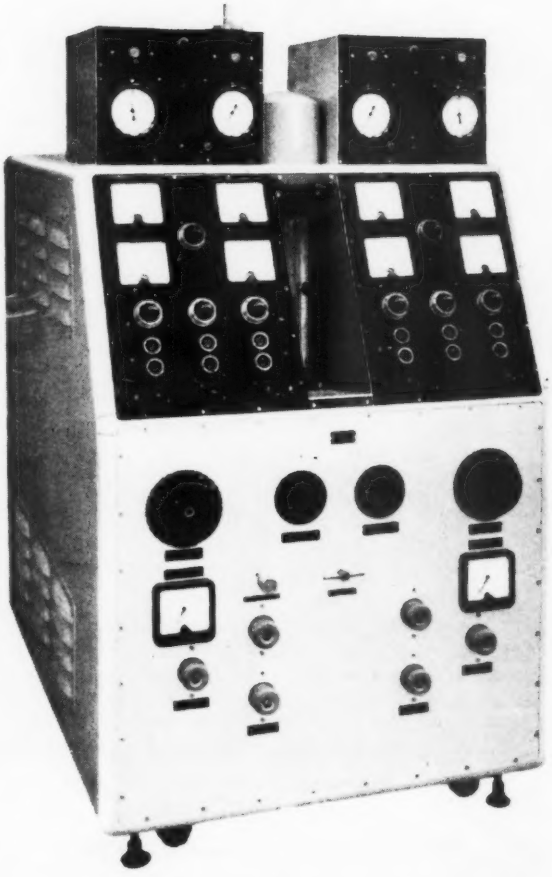

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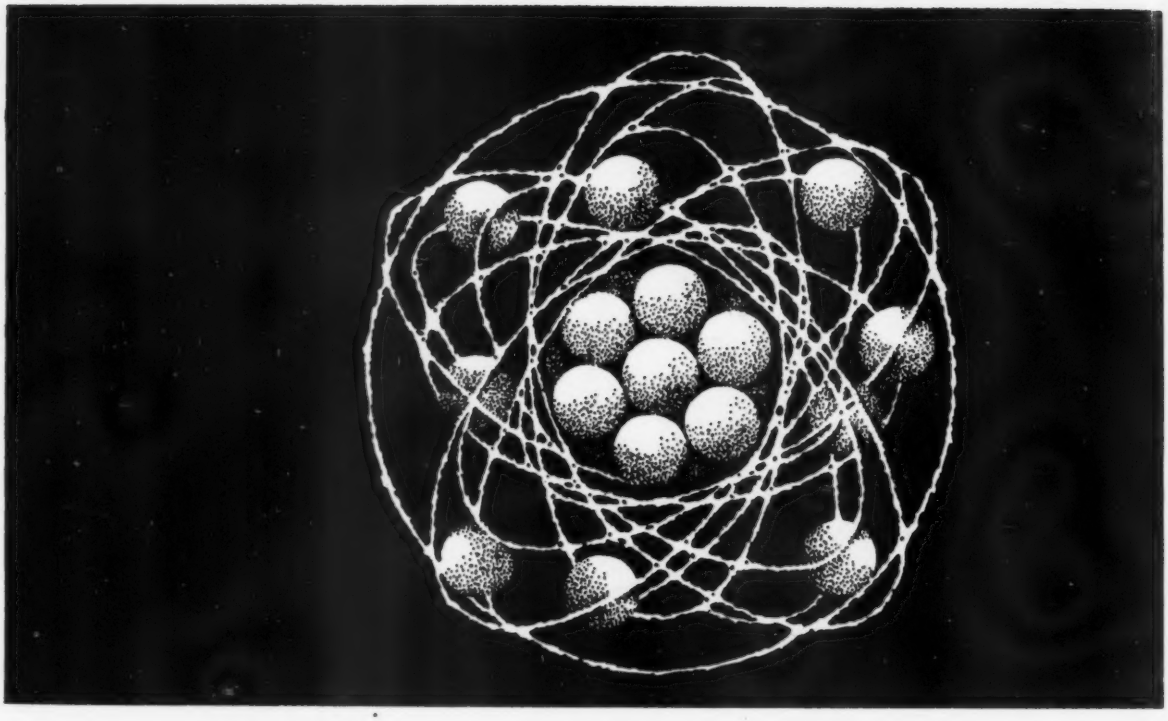

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The design of the ERHARD-Absperrklappen is not limited to the aforementioned temperatures and pressures, and we are in a position to manufacture valves in order to meet the severest temperature and pressure conditions arising in nuclear reactor power plants.

External means are used in order to urge the disc sealing ring on to or away from the valve seat for closing or opening the valve. Operation can be effected according to requirements by hand, electric, pneumatic and hydraulic means.

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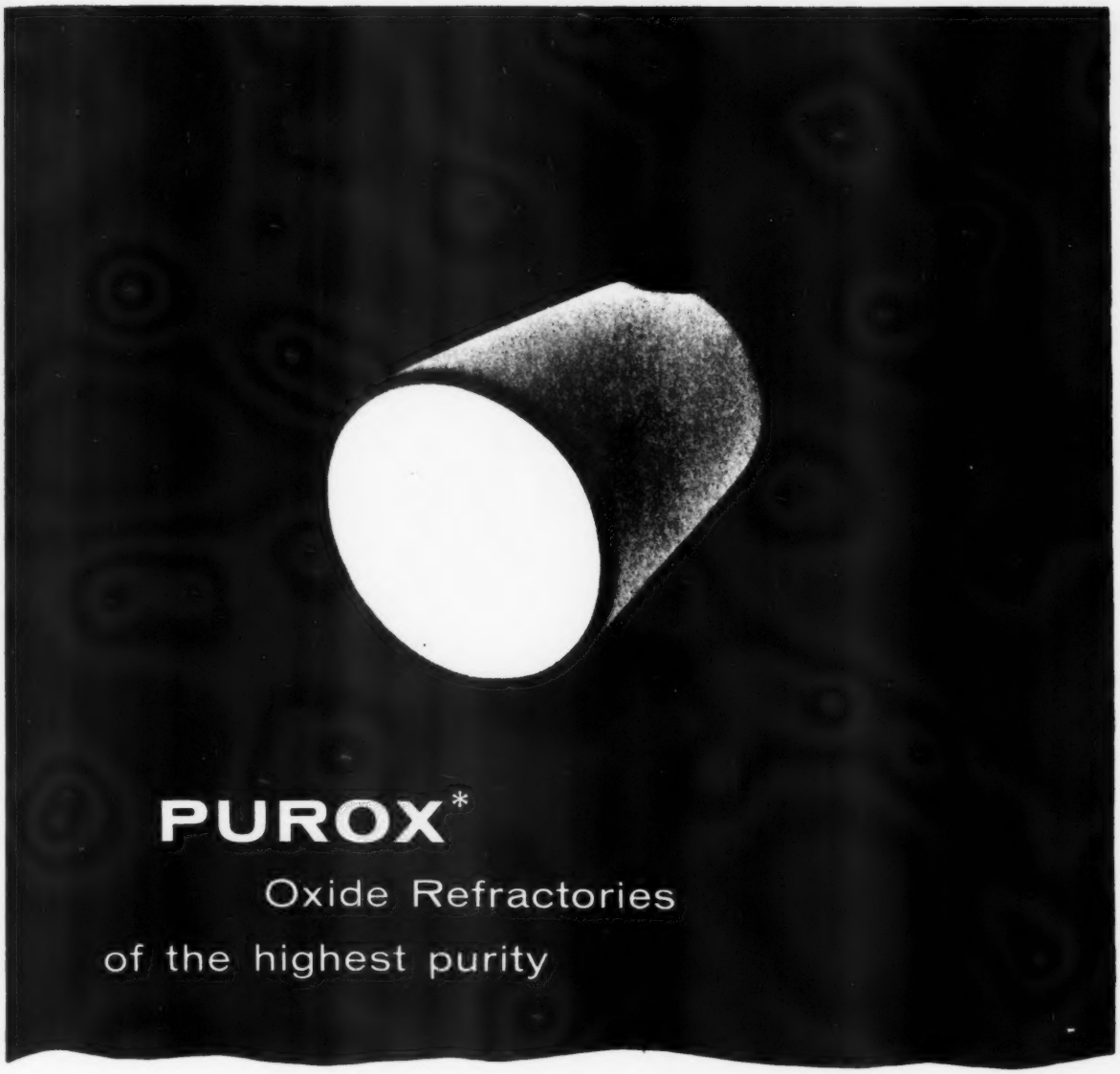

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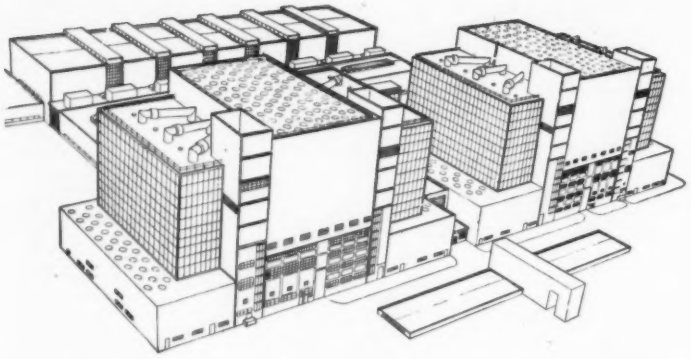

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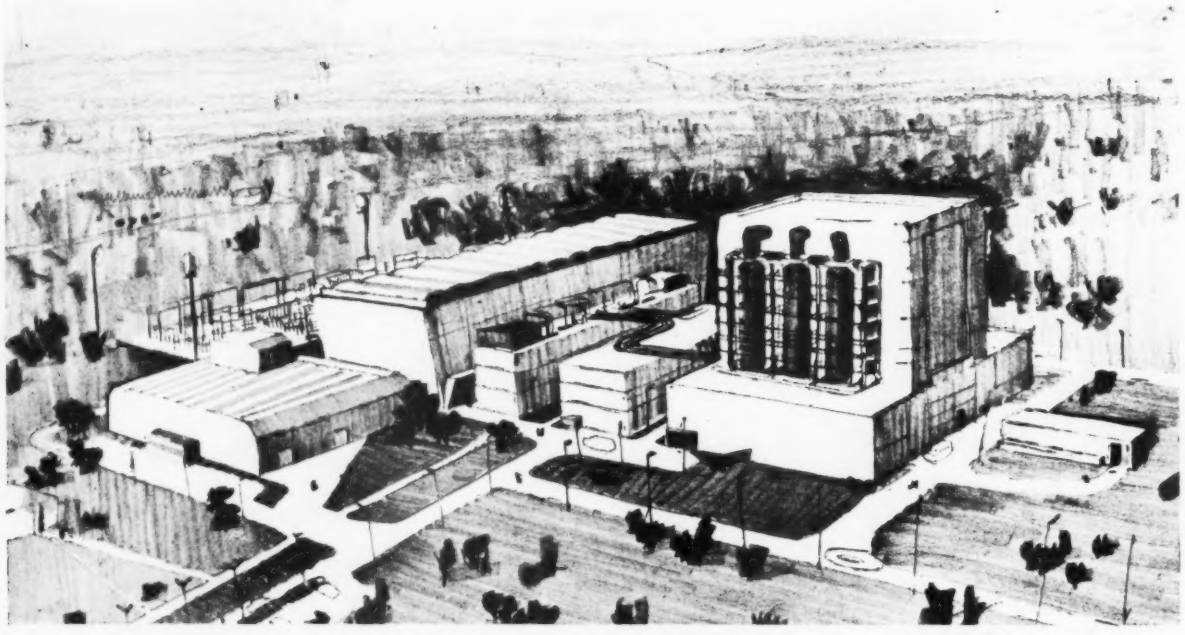

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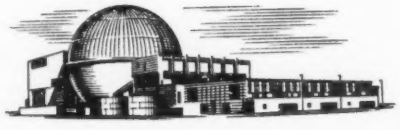
facing new fire problems in the sphere of nuclear power



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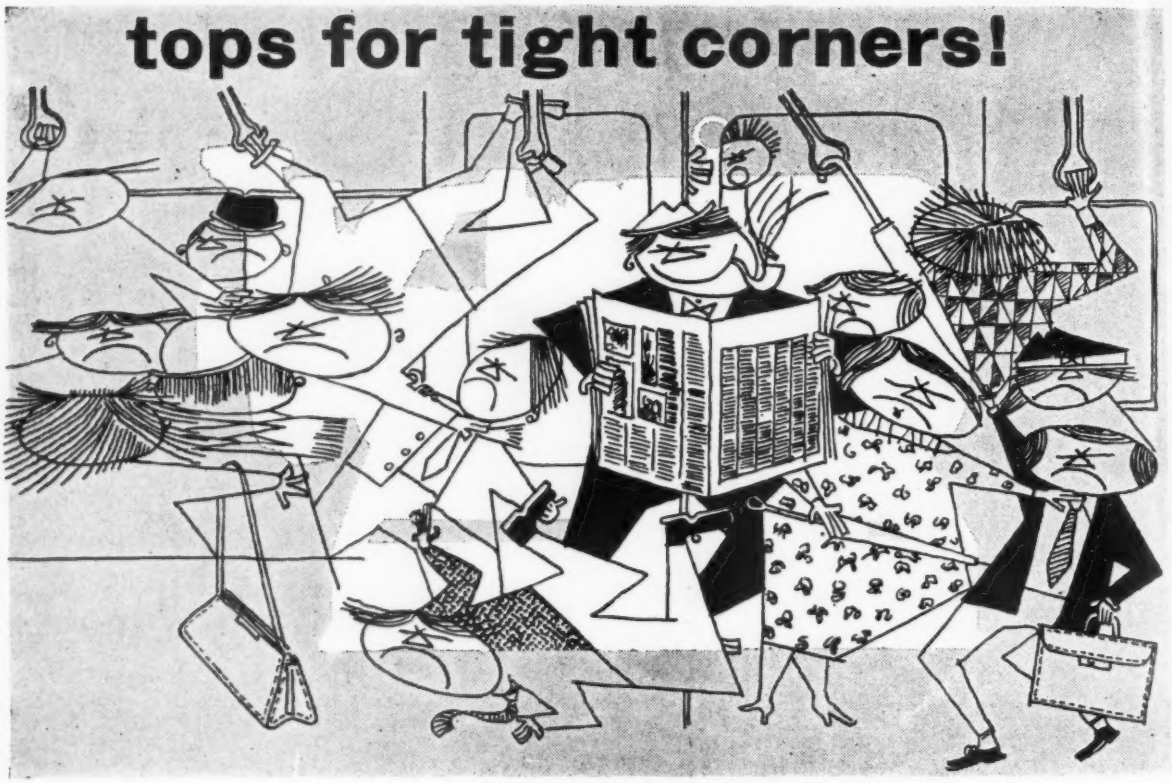

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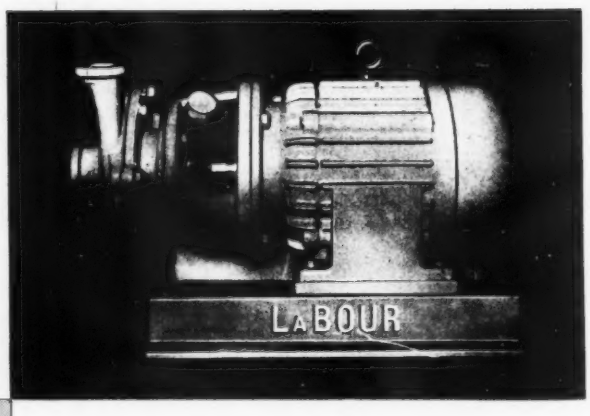

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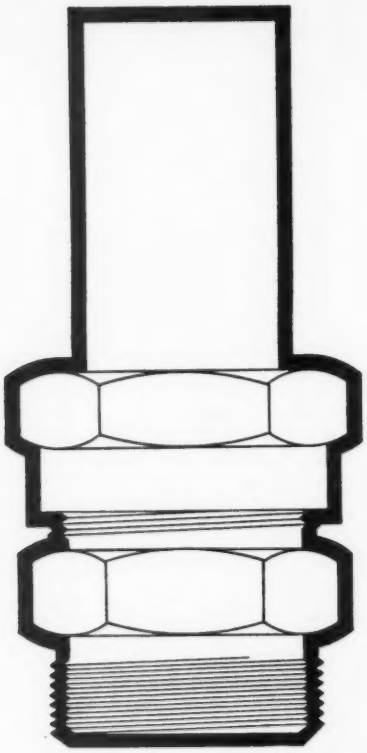
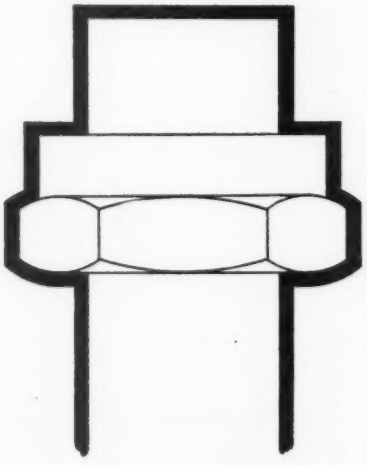


the applications of Ermeto high pressure couplings are practically unlimited



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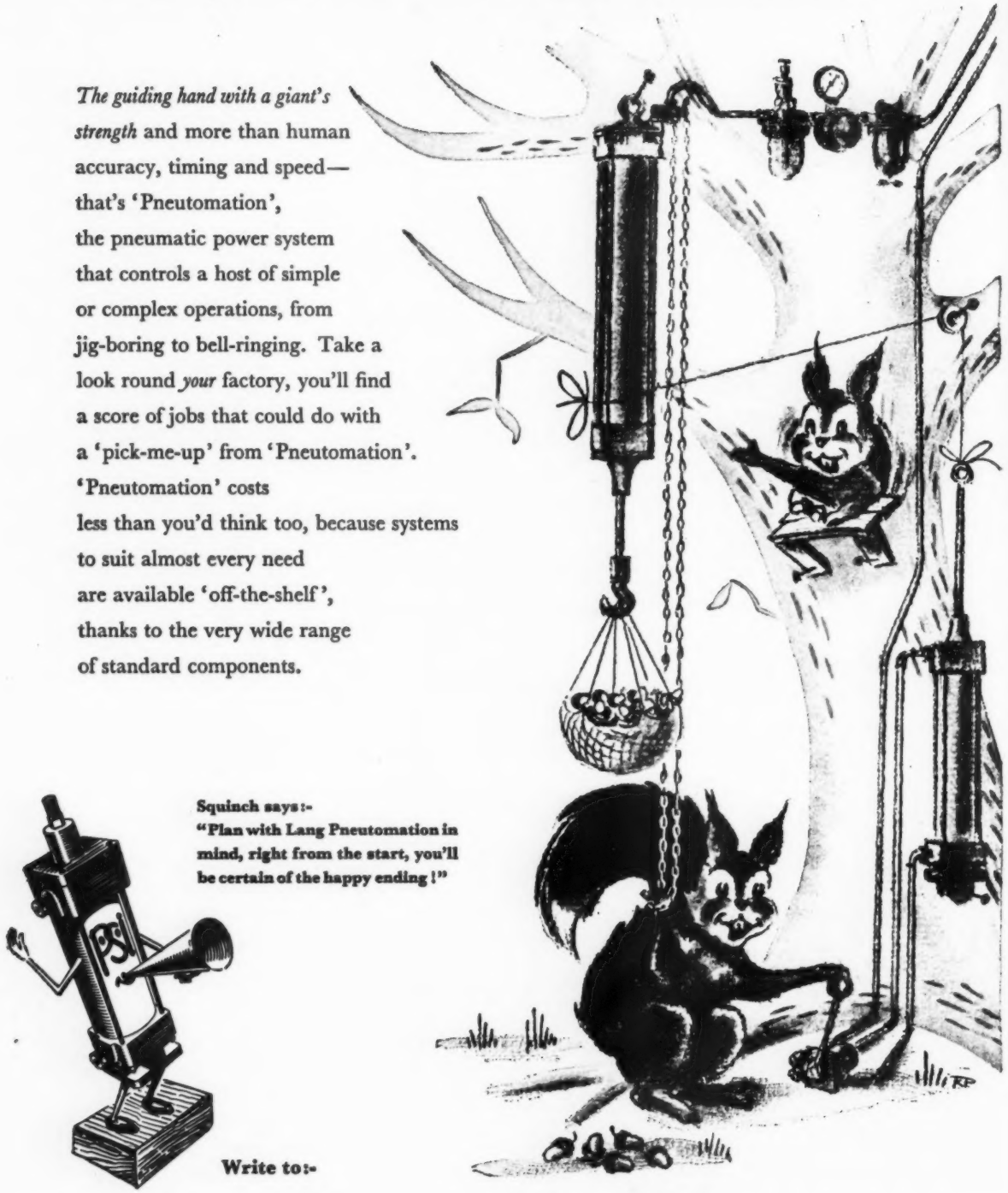

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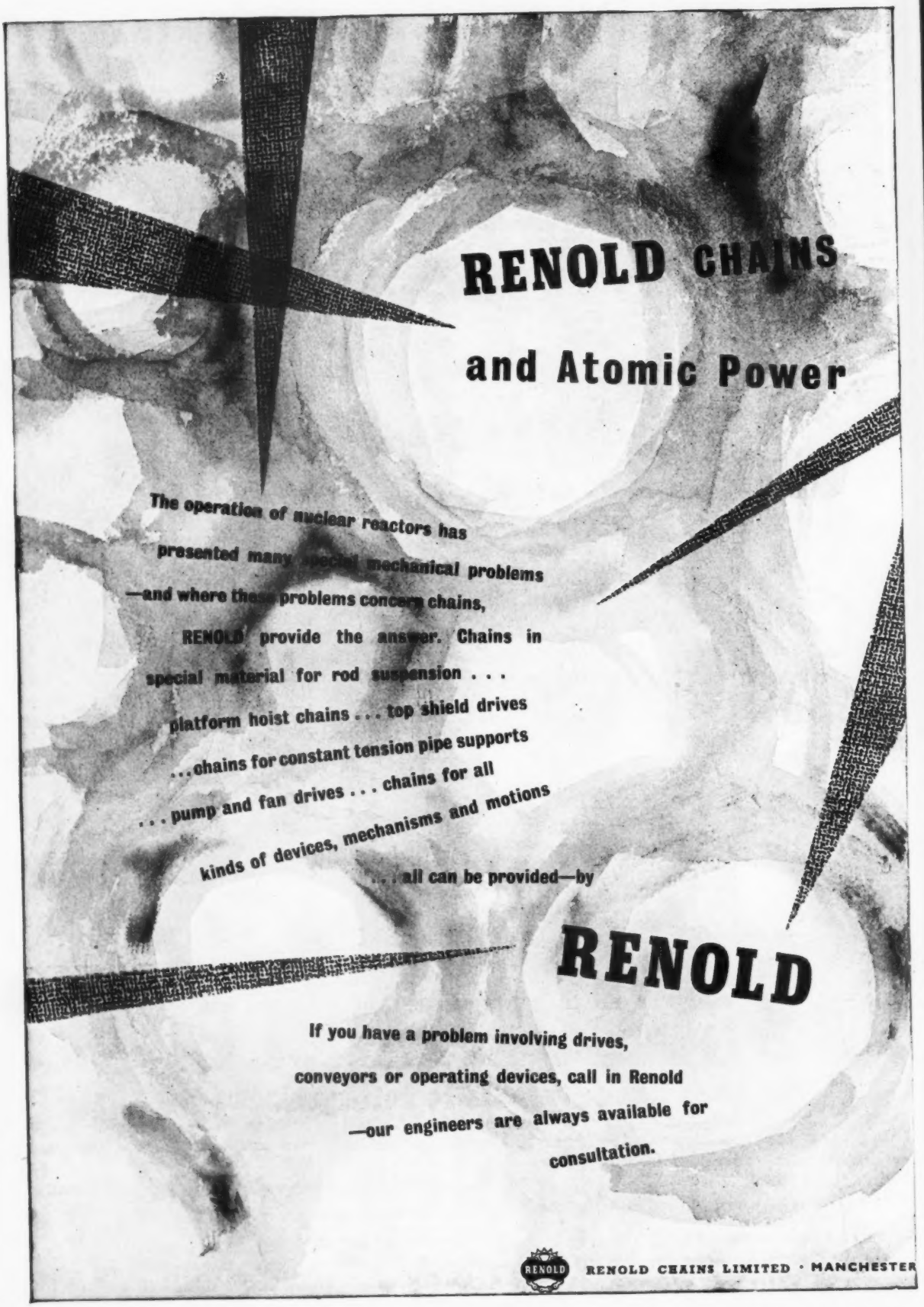
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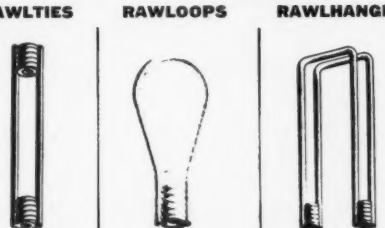

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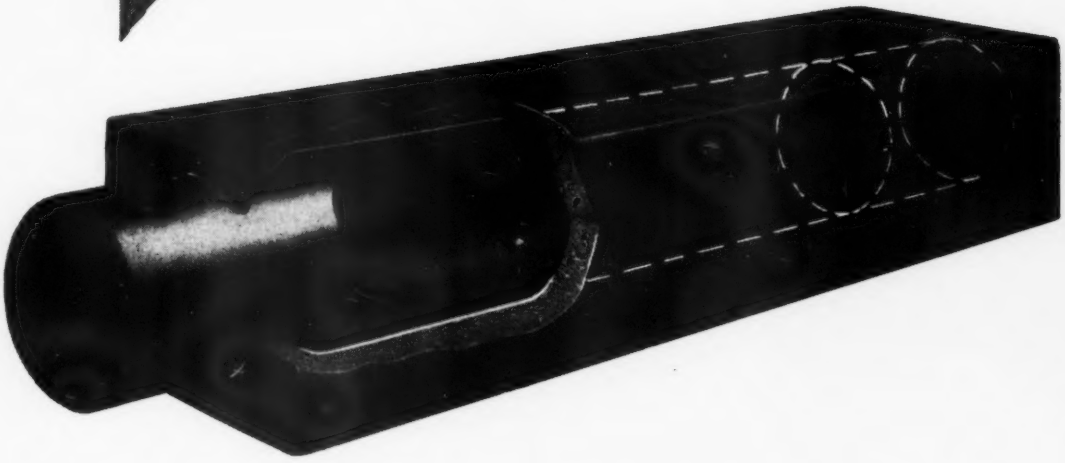

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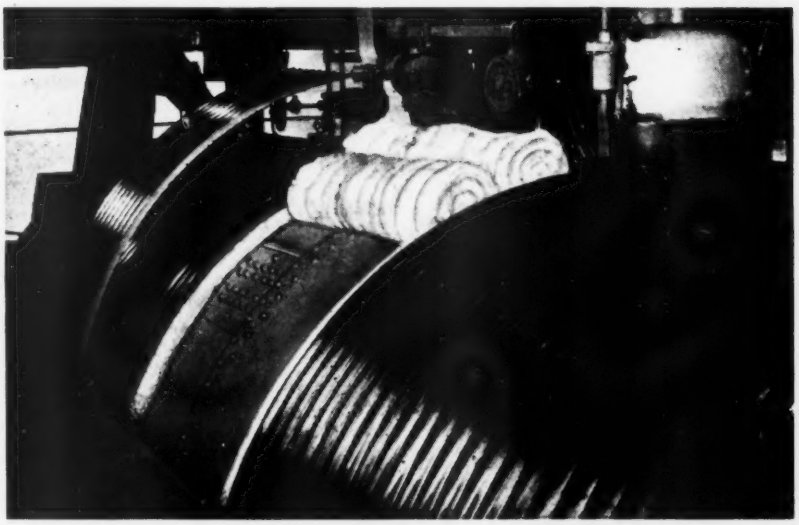

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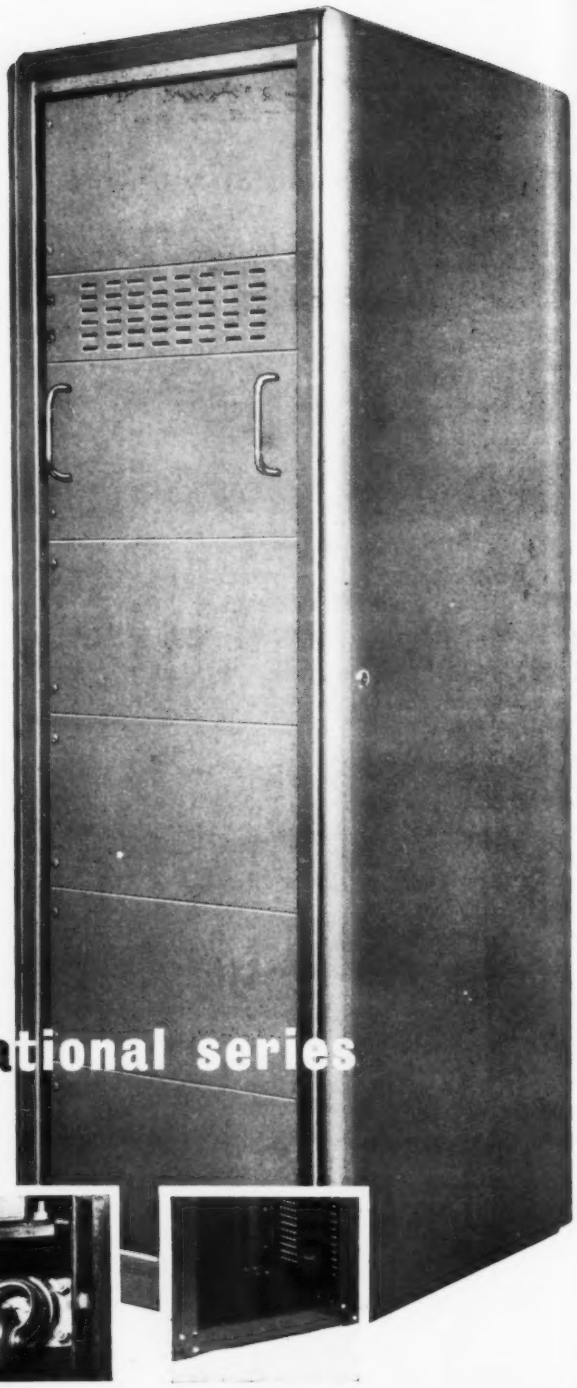

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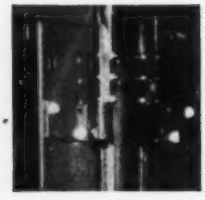
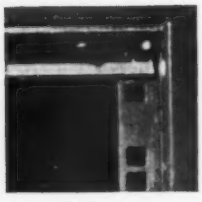


1 The strong, concealed lift-off hinges, of patented design, on the side doors



2 The quick-release mechanism allowing the rear door to be lifted easily off its hinges

3 Provision for fitting castors, obviating the need for mobile bases

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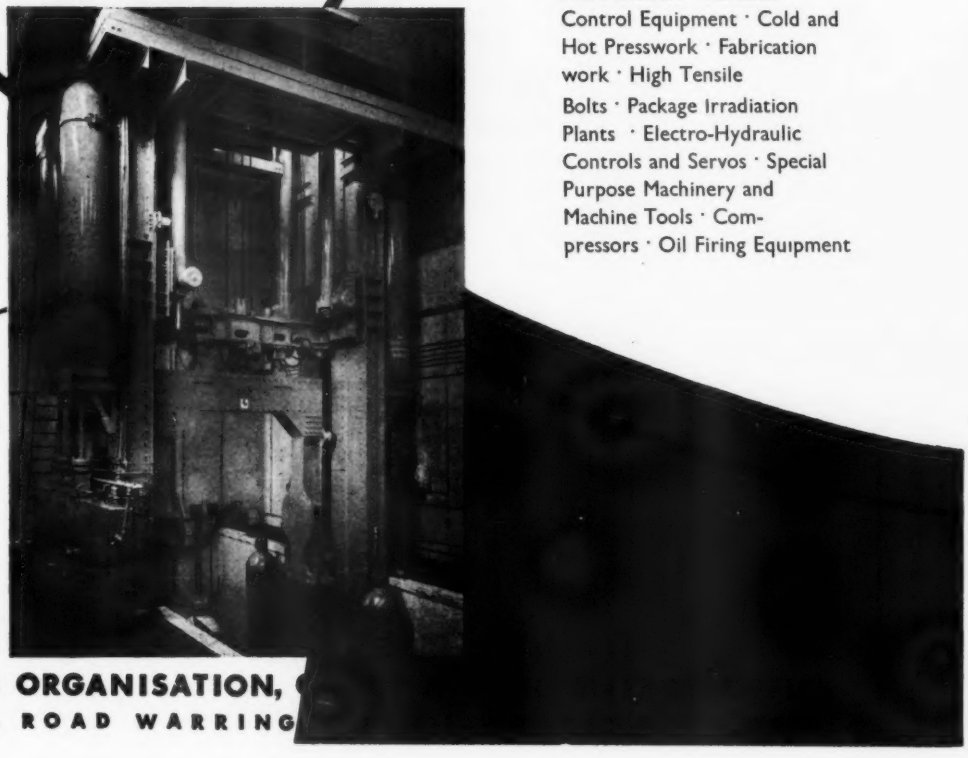

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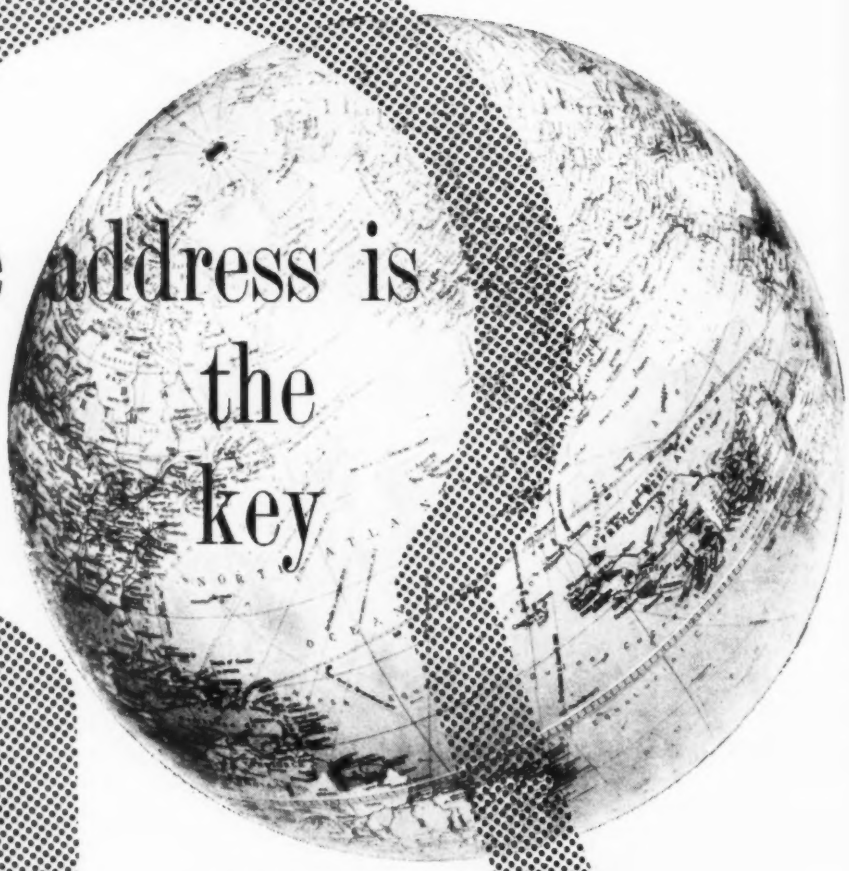

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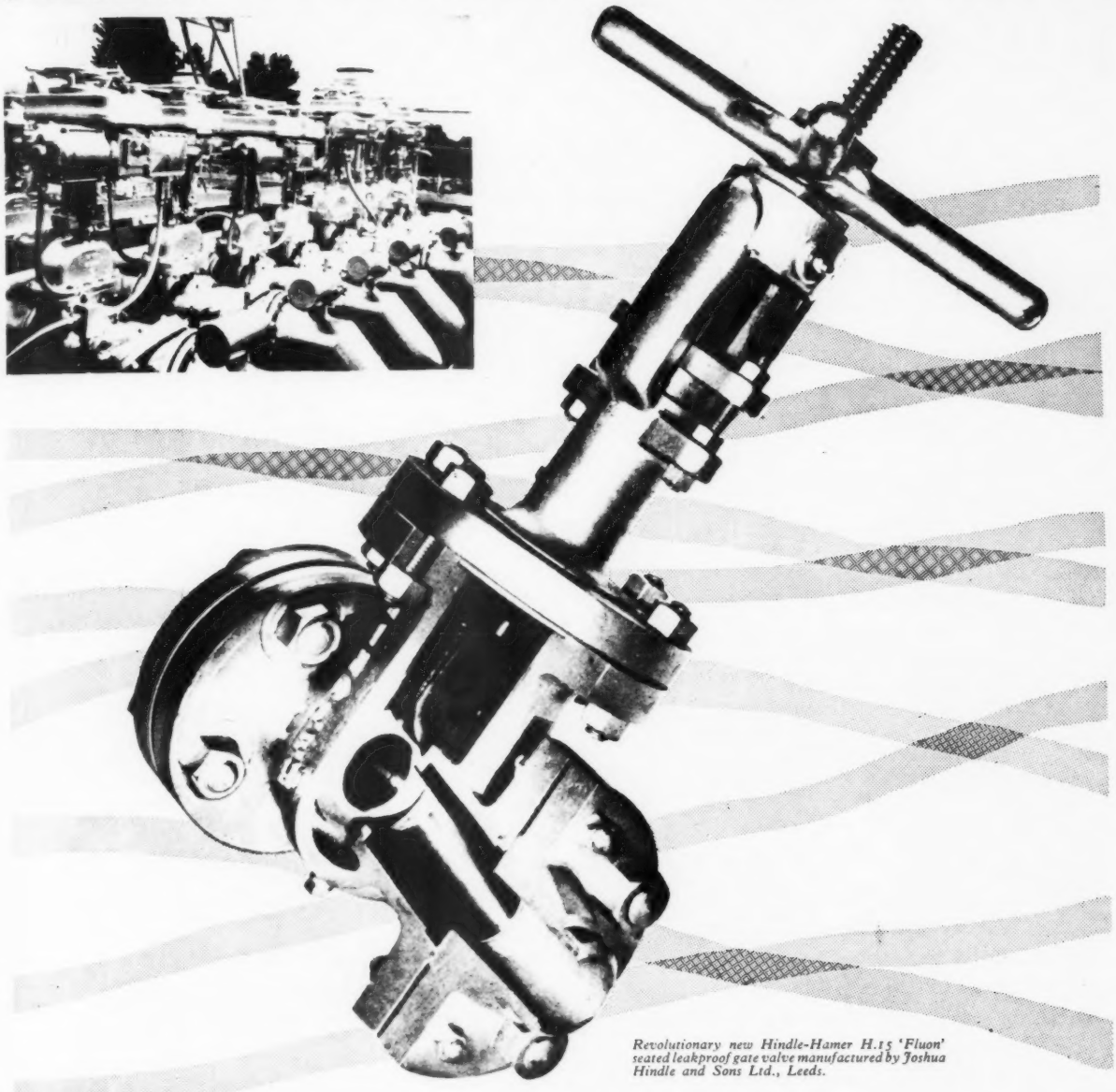

Revolutionary new Hindle-Hamer H.15 'Fluon' seated leakproof gate valve manufactured by Joshua Hindle and Sons Ltd., Leeds.

Only 'Fluon' could have brought about this valve revolution

BECAUSE OF 'Fluon' Joshua Hindle and Sons Ltd. were able to perfect a revolutionary new leak proof valve. Their Hindle-Hamer H.15 gate valve incorporates a double sealing action. In addition to metal-to-metal fit of the wedge against the valve seats, two 'Fluon' p.t.f.e. seals are compressed against the wedge as it is lowered. This combination sealing action provides a positive shut-off both upstream and downstream, doing away with the need for a double block and bleeder in piping installations.

Had metal been used instead of 'Fluon', an eventual leak would have been unavoidable. 'Fluon', however, has a superior resistance to an extremely wide range of chemicals and, what is of tremendous importance, is not subject to pitting. That this 'Fluon' seated gate valve is perfectly leakproof has been proved both in practice and by exhaustive tests. After accelerated tests — equalling three years actual use — the valves were still in perfect condition and 100% leakproof. Undoubtedly, the Hindle-Hamer H.15 'Fluon' seated gate valve is ideal for any heavy duty application where a leakproof valve is essential.

'FLUON'

'Fluon' is the registered trade mark for the polytetrafluoroethylene manufactured by I.C.I.

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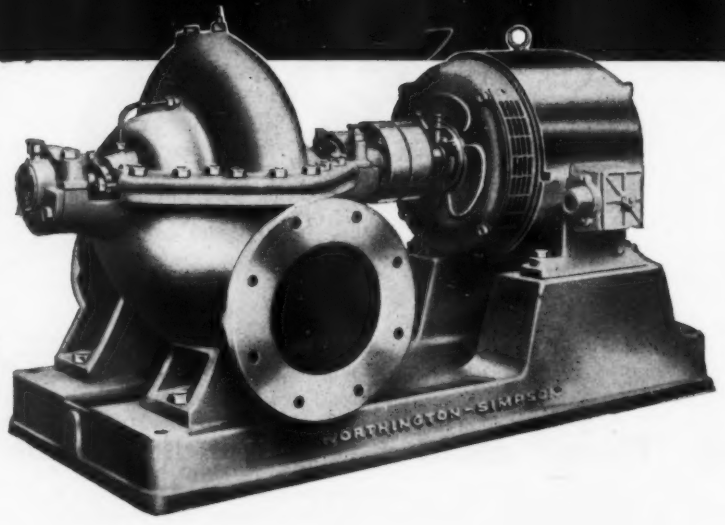

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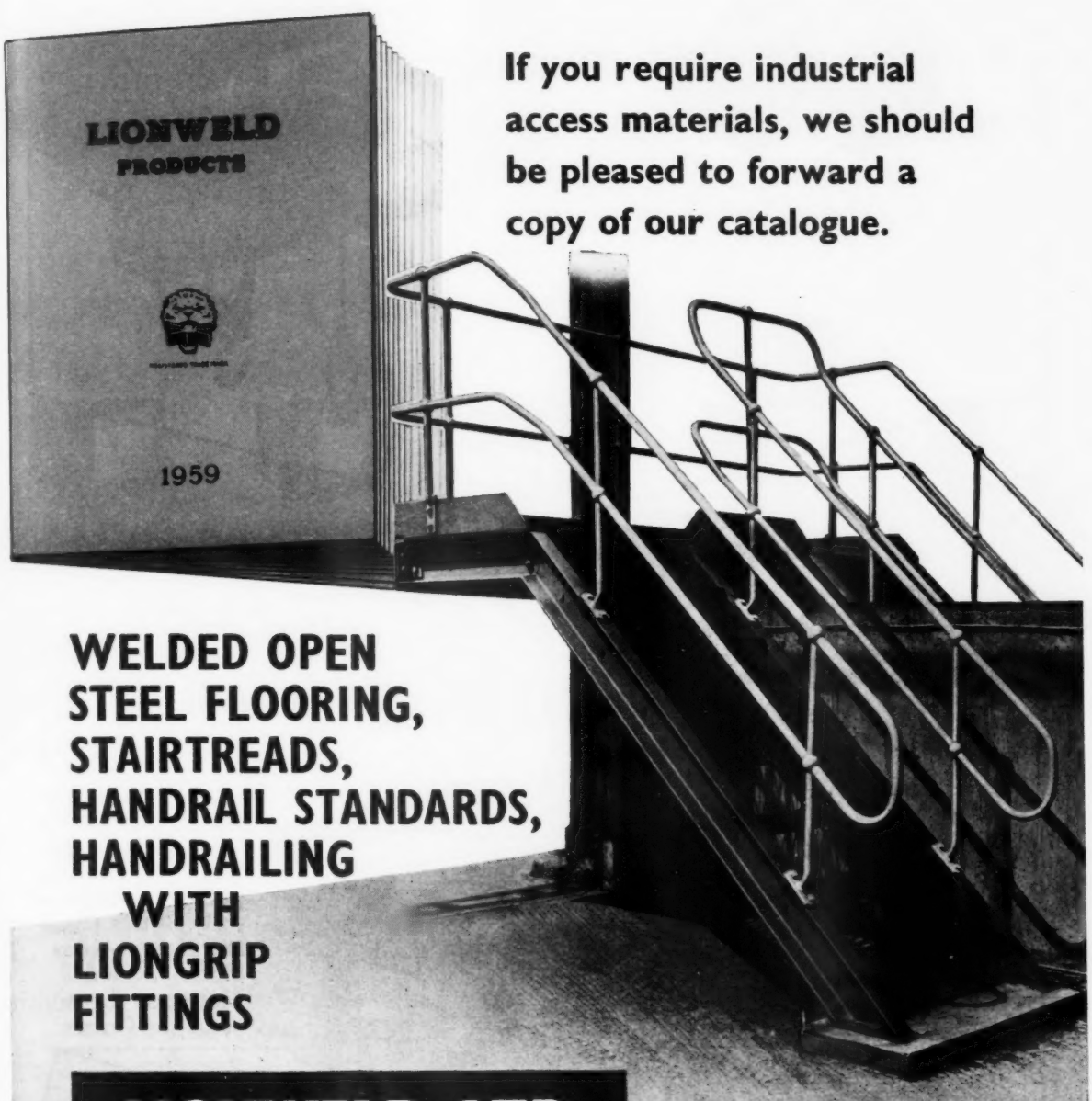

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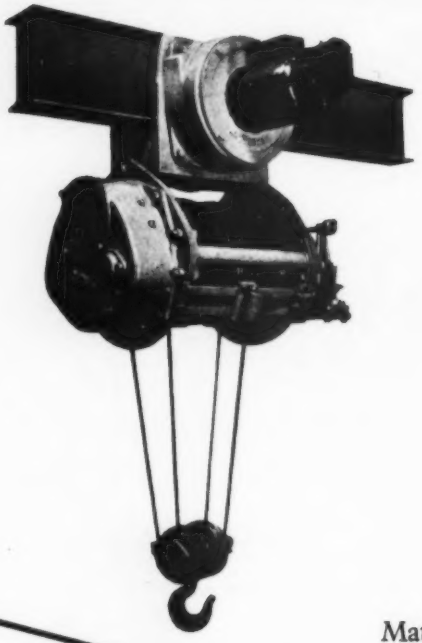

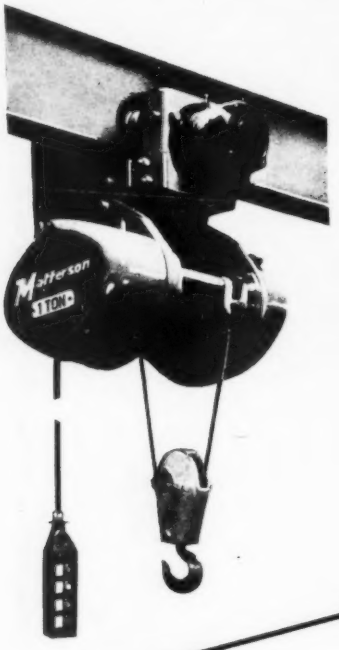

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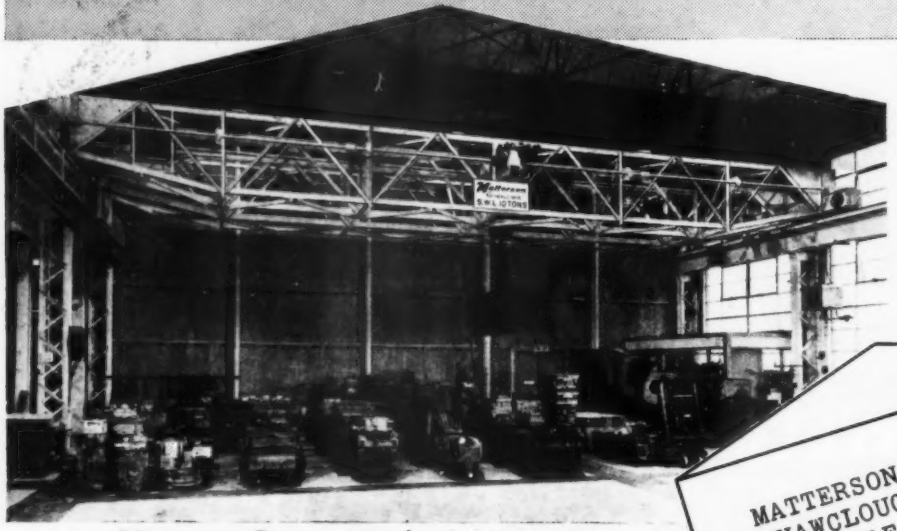

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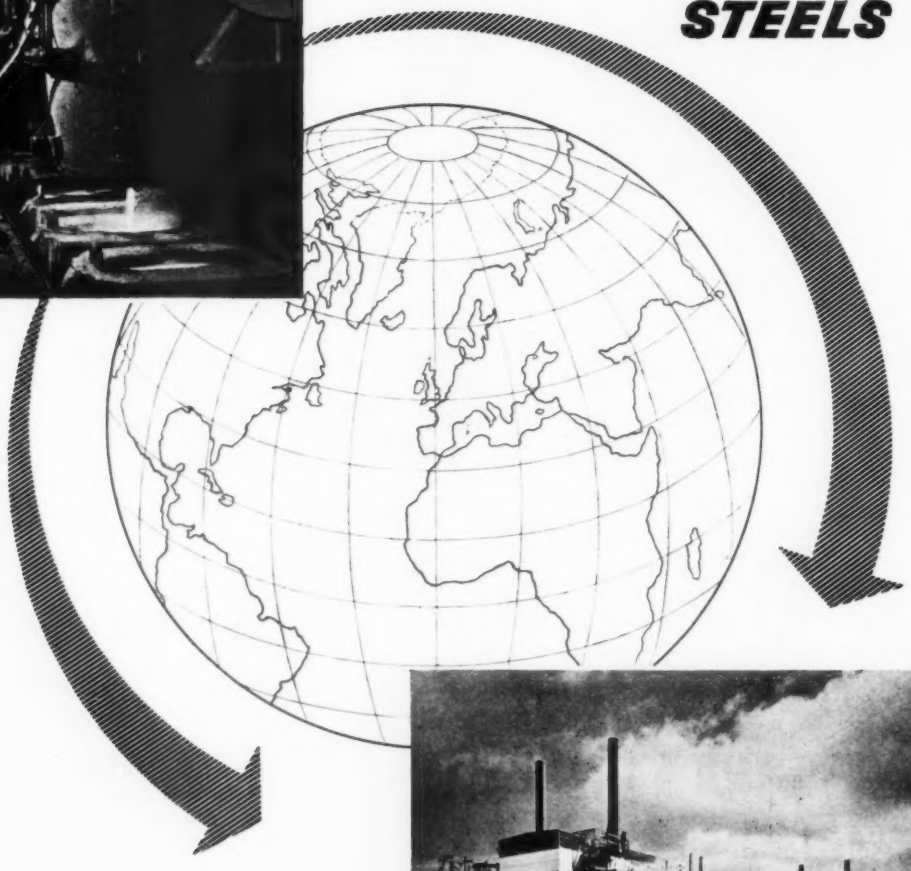

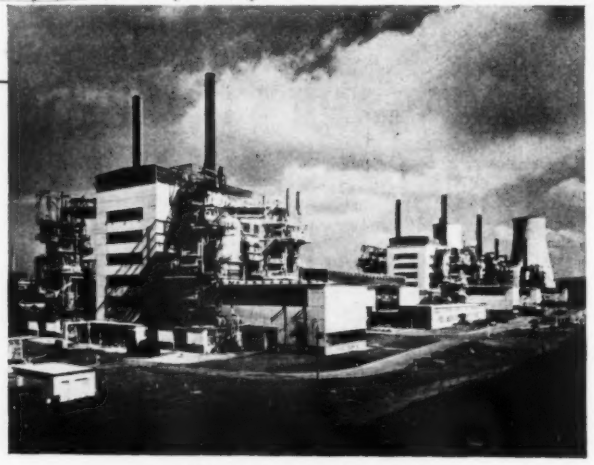

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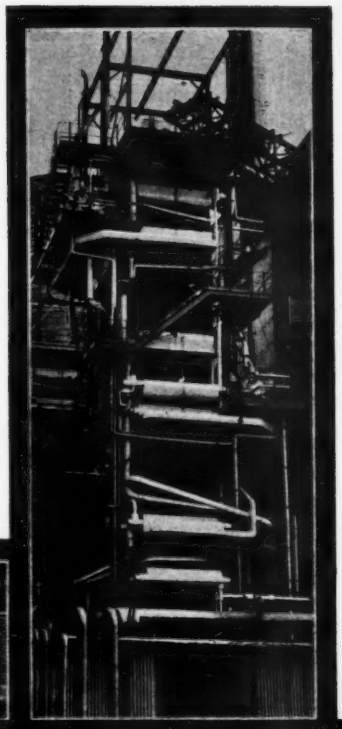

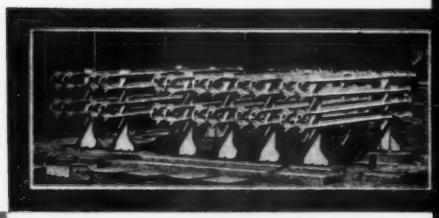

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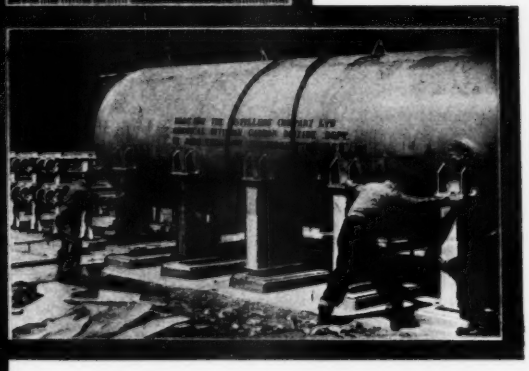

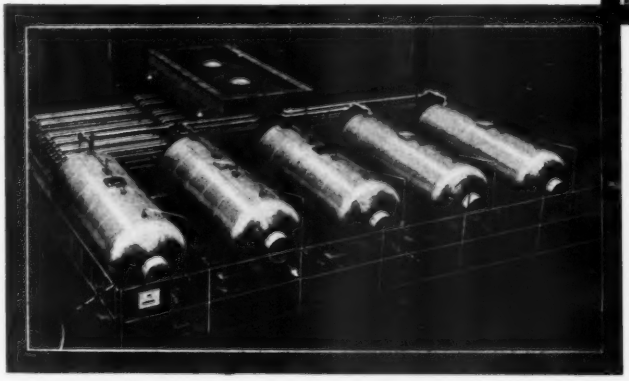

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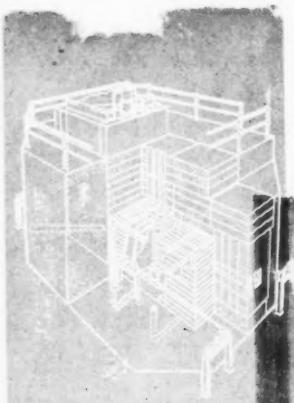

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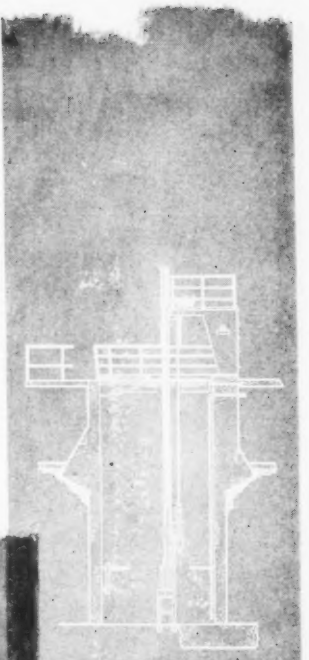

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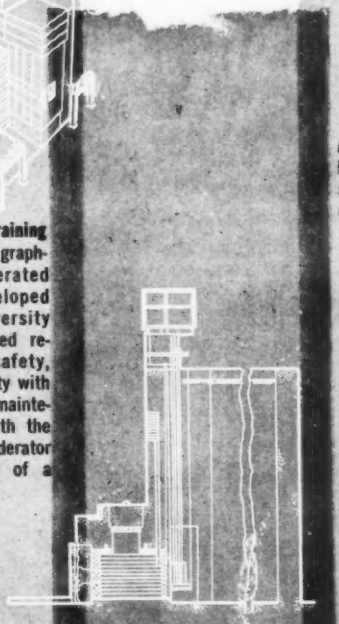

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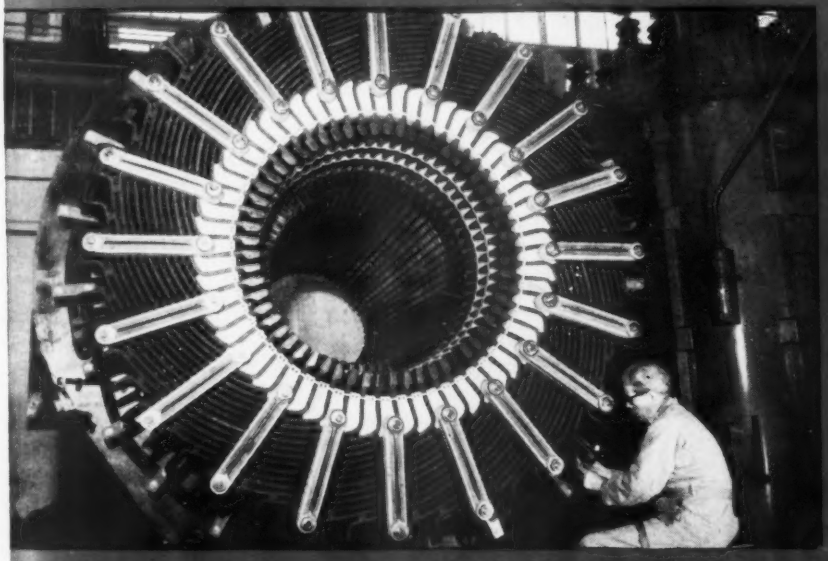

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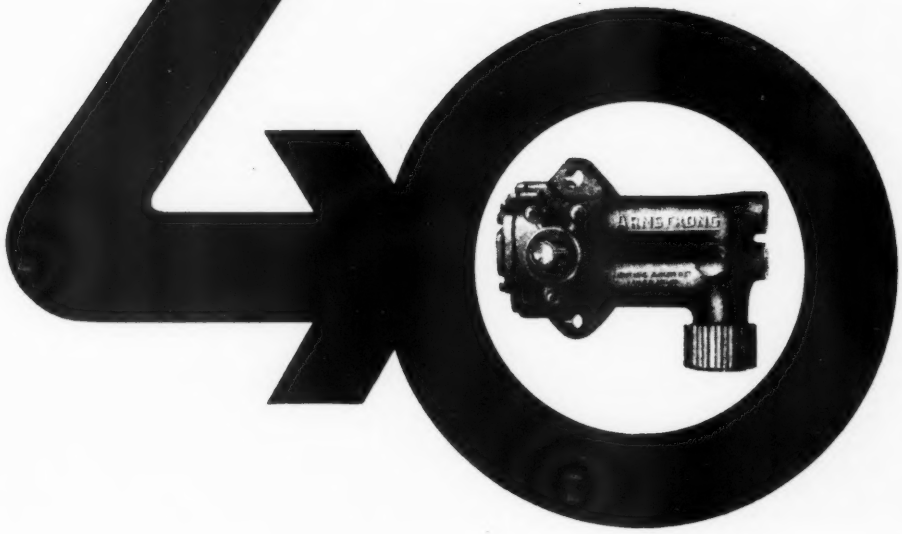

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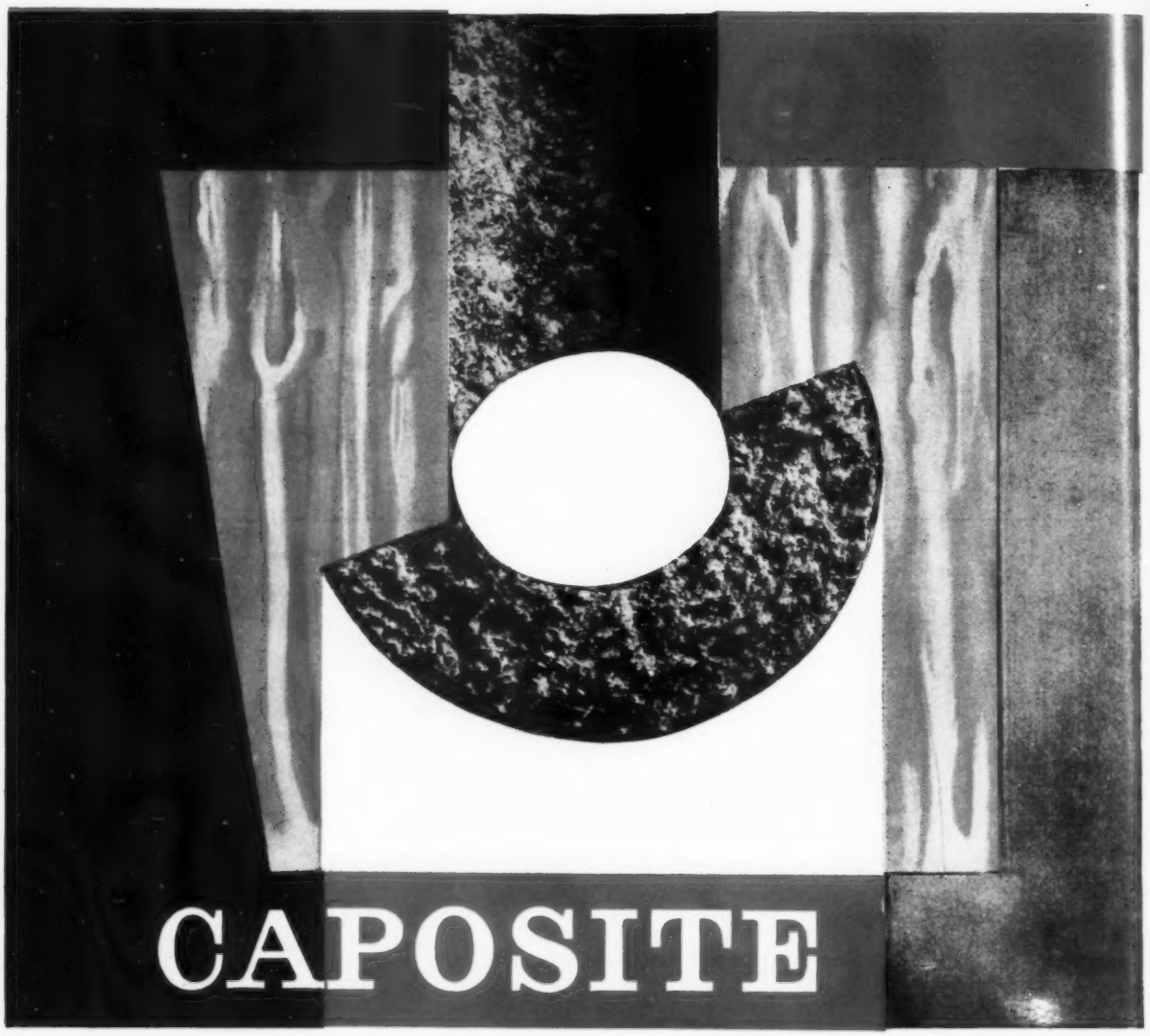

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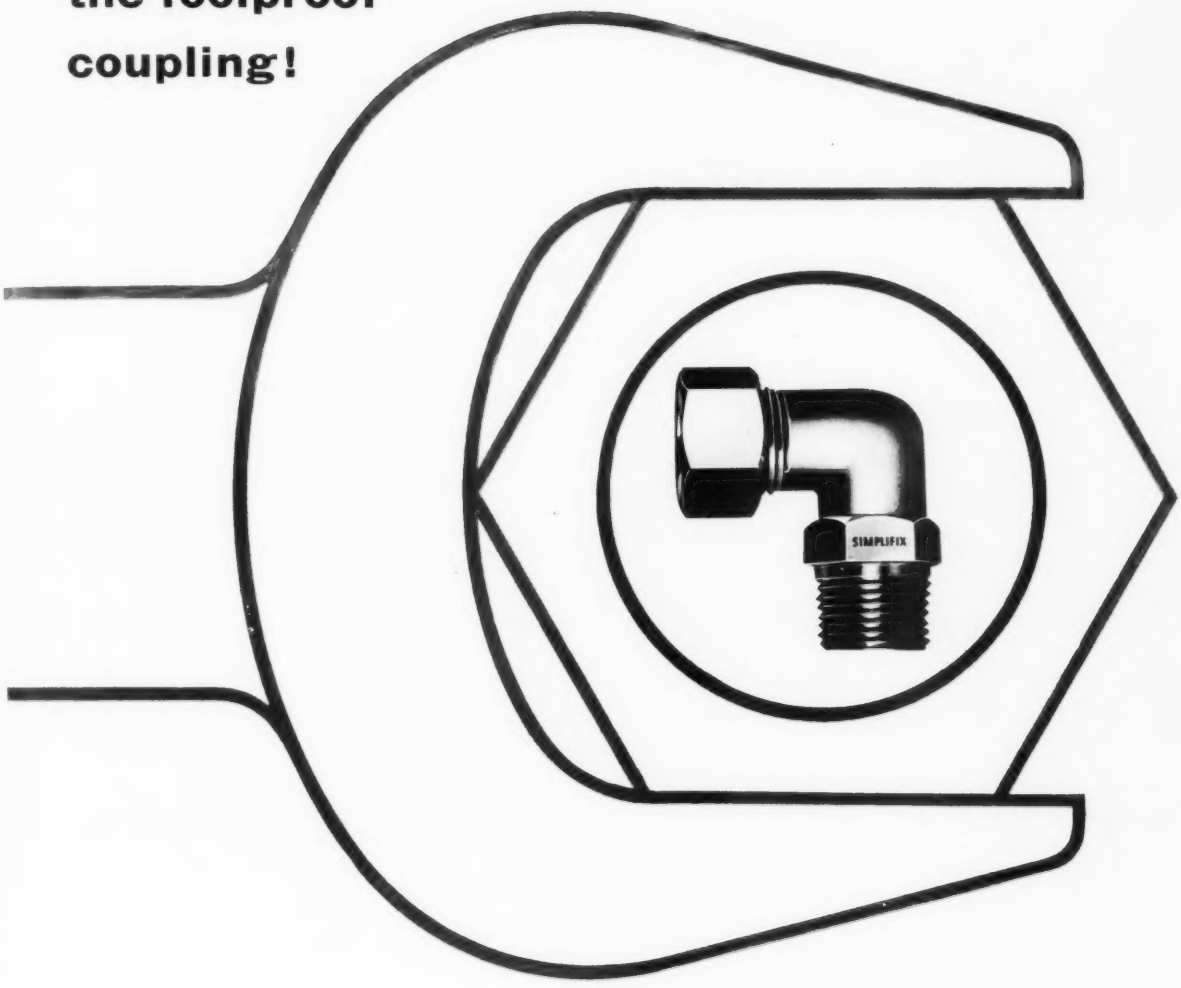

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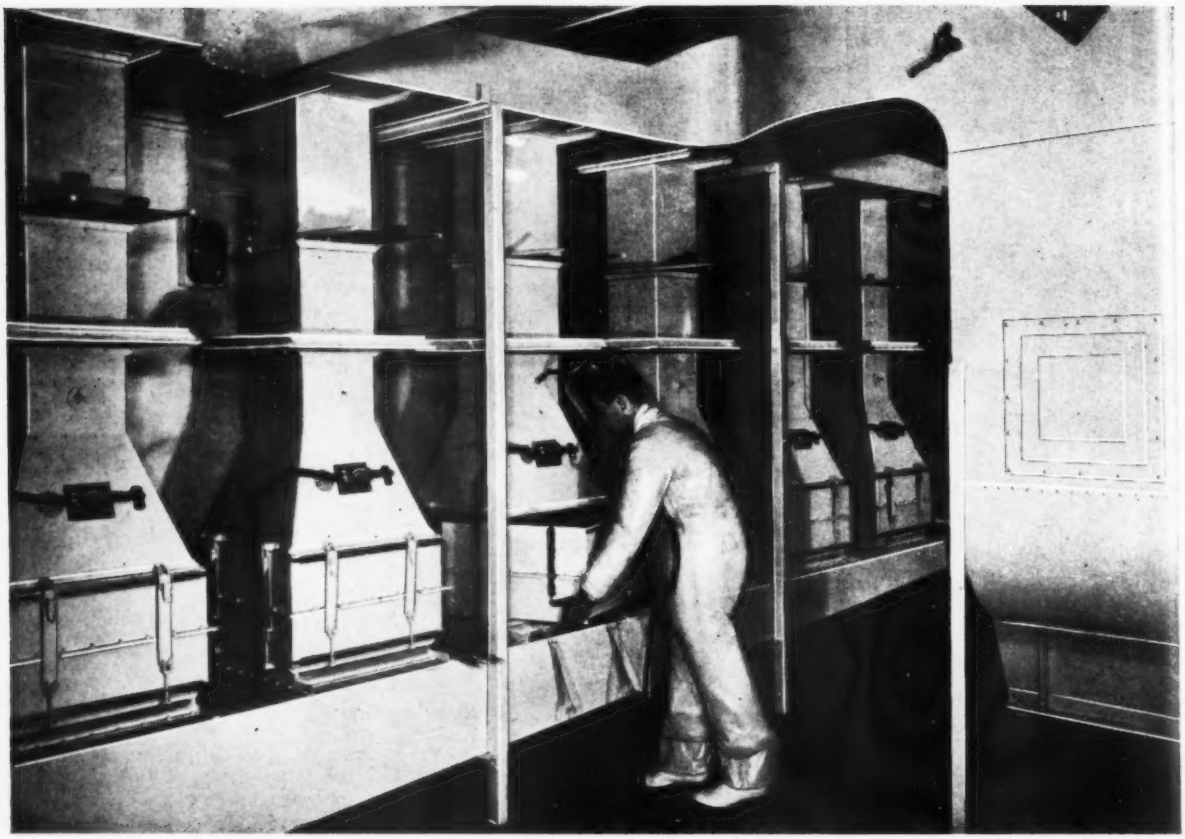

One of two banks of Vokes 'Absolute' filters in the G.E.C. beryllium laboratory, showing operator in a pressure suit changing a filter.

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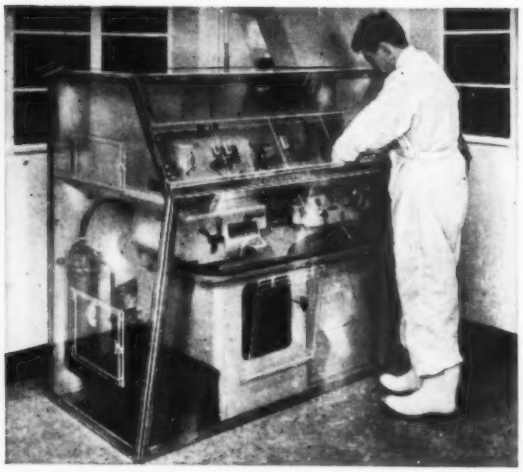

A Vokes filter can be seen on the left of the lathe enclosed in the PERSPEX working box.

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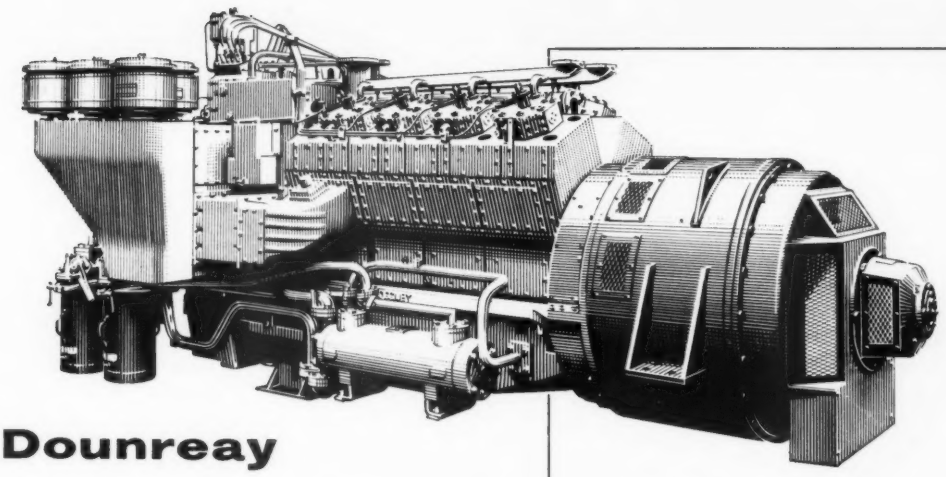

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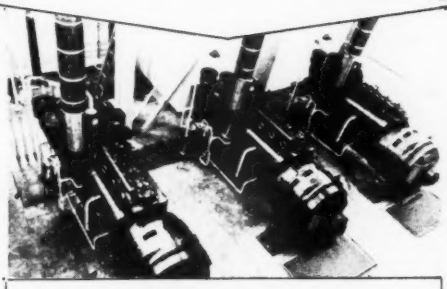

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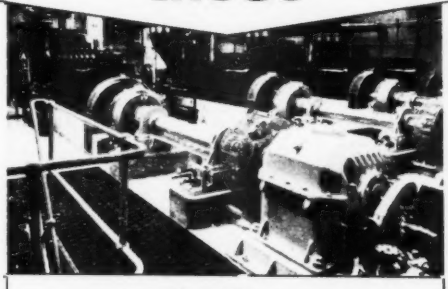

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One "ESN" three cylinder engine rated at 192 b.h.p. at 960 r.p.m. arranged to start up automatically on mains failure and take over the drive of an electric motor, without interruption of the ventilation system.

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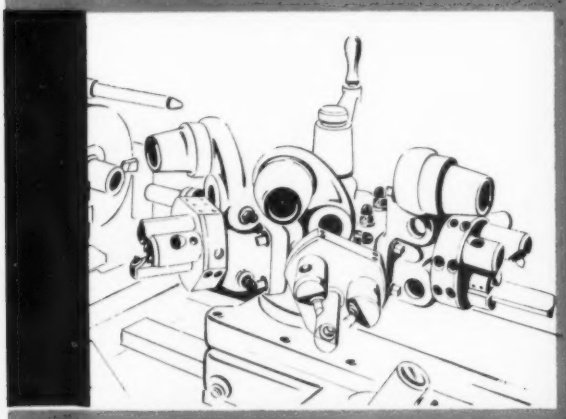

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(Regd. Trade Mark)

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FOR LOADS UP TO 8 TONS
PIPE MOVEMENTS UP TO 18"

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British Patent No. 474008, 720074, 720075, 697987, 657318
U.S.A. Patent No. 2129320

Ferrybridge 'B' Power Station. Central Electricity Generating Board, Yorkshire Division. H.P. Steam Pipes supplied and installed by Stewarts & Lloyds Ltd.

Leibfried Red Top Pipe Supports for loads from 100 to 5,000 lbs. and total travel of 3".

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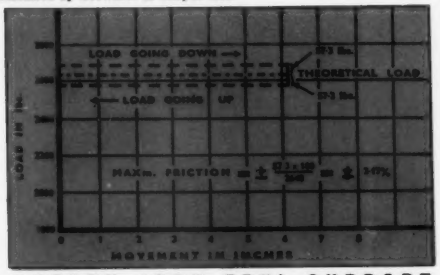
From graph it can be seen that the maximum friction is equivalent to 2.17% of the applied load.



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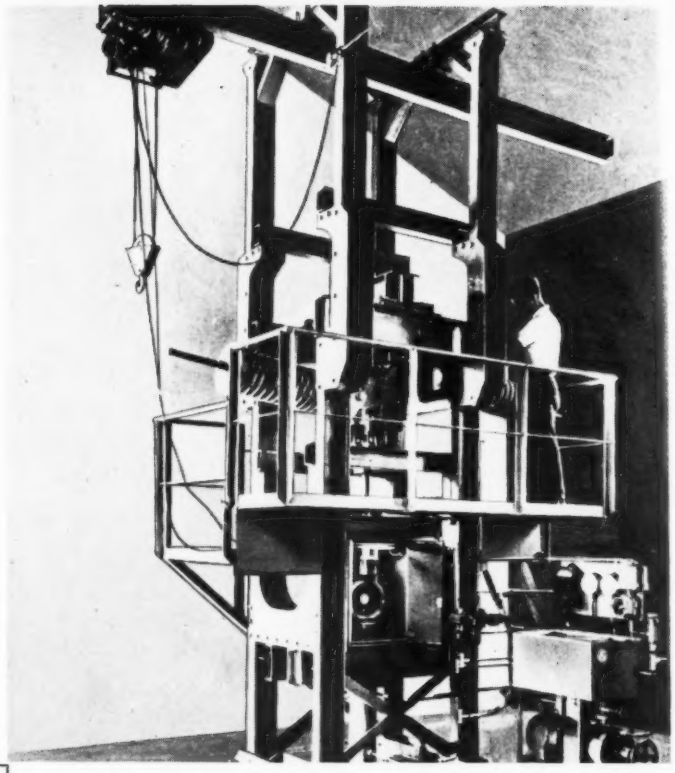
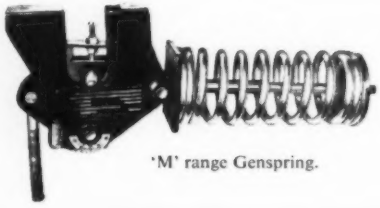
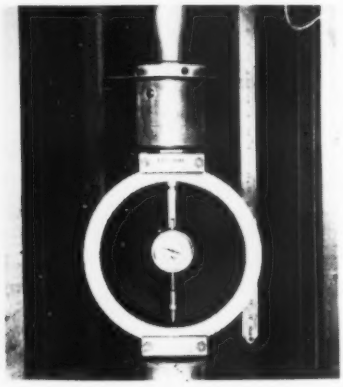


Test rig for heavy-duty Gensprings.



'M' range Genspring.

Strain gauge, calibrated by the N.P.L.



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Recently an *independent* research laboratory carried out a ten week corrosion test on a Genspring. Using the A.R.E. salt droplet test (B.S.S. 1931. 1952) they proved that the equivalent of 20 years exposure to severe marine atmospheric conditions had no appreciable effect on the Constant Support Hanger's mechanical efficiency. A copy of the report is available on request.

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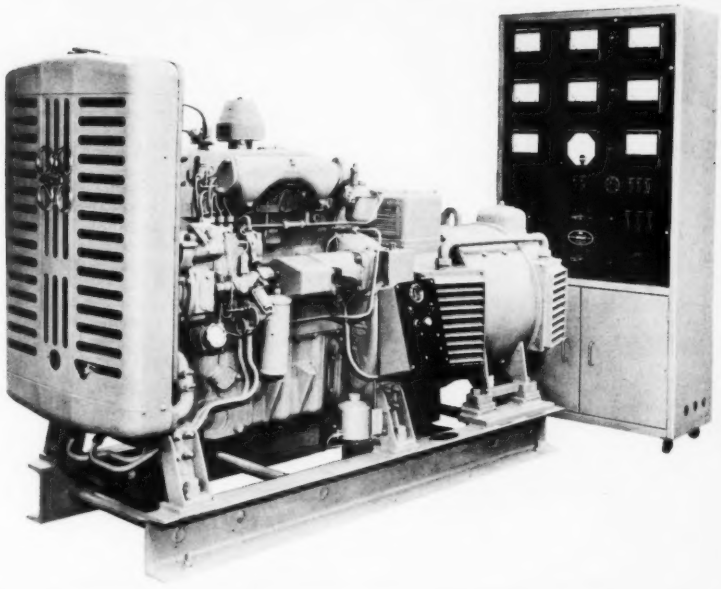

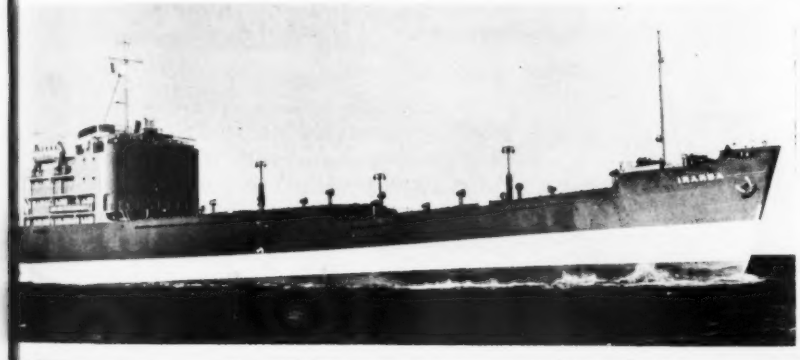

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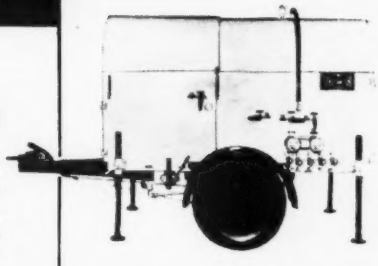

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Pyrotenax

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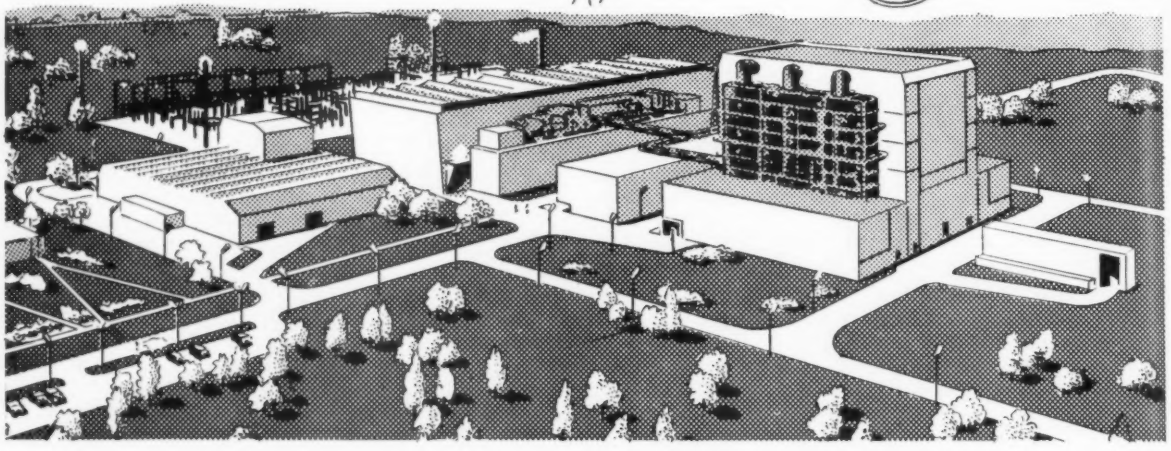

Considerable quantities of Pyrotenax mineral insulated metal-sheathed Thermocouples with equally similar quantities of Compensating Cable have been specified for this new Nuclear Power Station mainly for the temperature measurement of the concrete biological shield surrounding the reactor, the graphite blocks and the reactor vessel, as well as for various other ancillary applications.

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Full technical details in Publication 31/x.121

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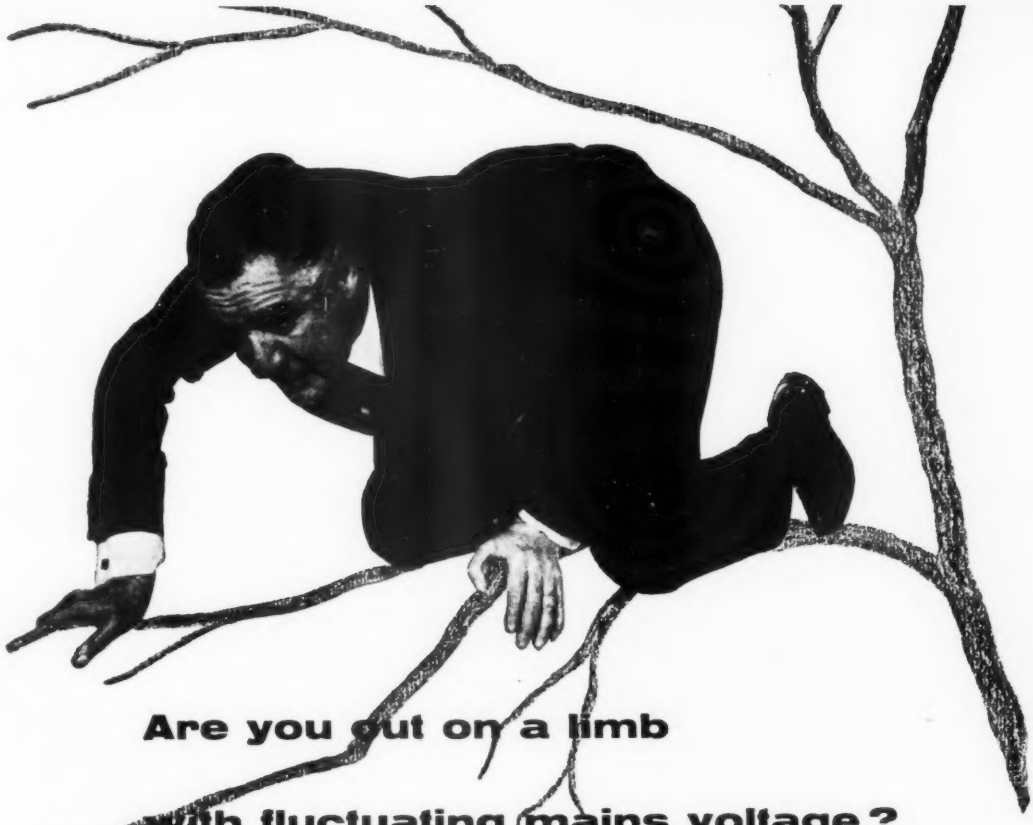
GD121



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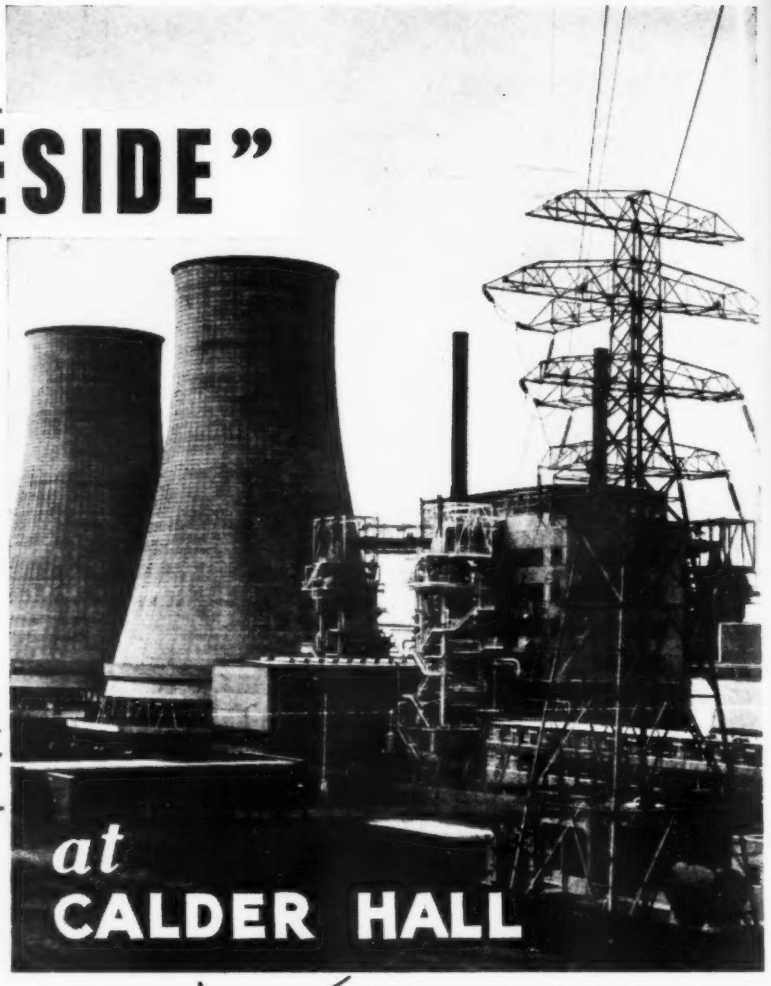

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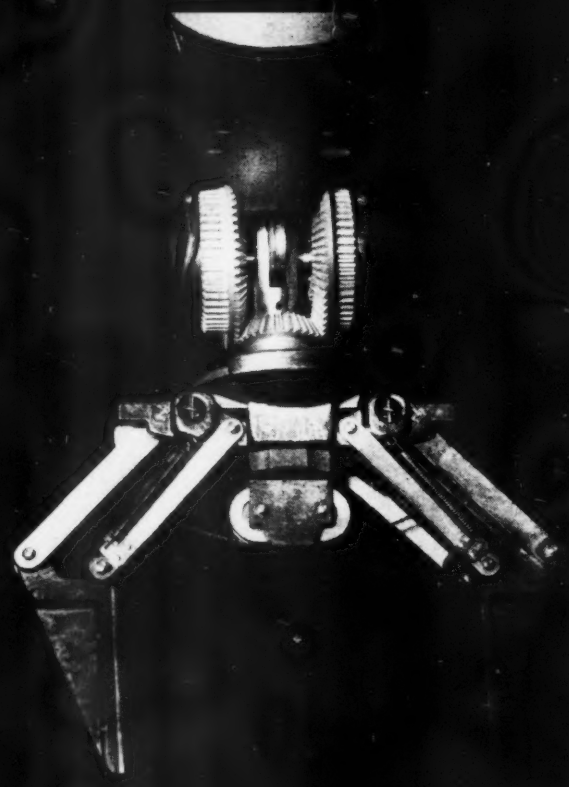

Manipulators

The manipulators used at atomic establishments have to operate under exacting conditions. They are constructed of stainless steel and Kanigen plated aluminium and the plate serves two functions. It resists corrosion and, because of the smoothness of the finish, it also assists in decontamination of the component parts from radio-active material; and the combination of stainless steel and Kanigen plated aluminium reduces the electro potential difference between the component parts. These manipulators, manufactured by Savage & Parsons Ltd., are supplied to users all over the world. Kanigen is used on the aluminium parts of the Tong End assembly and the Ma ter Hand assembly.

Kanigen

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KANIGEN is a nickel-phosphorus plate deposited by chemical reduction: thickness can be controlled to fine limits and is of complete and uniform coverage.

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Composition	92% Nickel 8% Phosphorus
Melting point	890°C.
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Hardness	500—1,000 V.P.N. according to heat treatment
Coverage	Extremely uniform

Kanigen can be applied to all ferrous metals, aluminium, copper and brass. The plating plant at Oldbury has now been extended, two extra plating tanks are in operation and enquiries for jobbing plating are welcomed. Full information is available on request.

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KANIGEN

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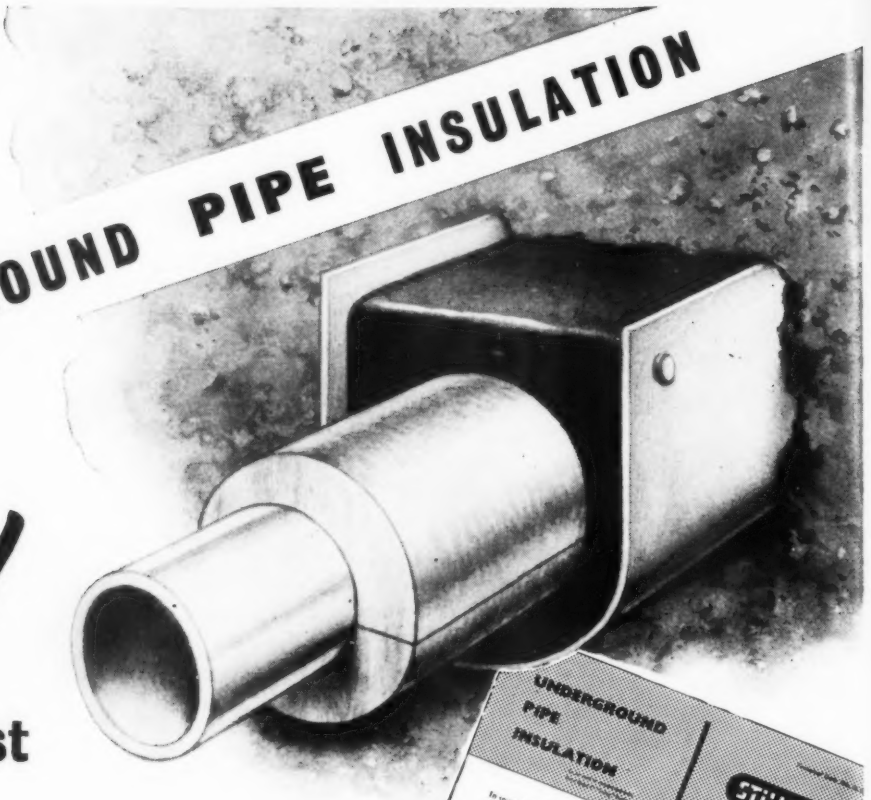
UNDERGROUND PIPE INSULATION



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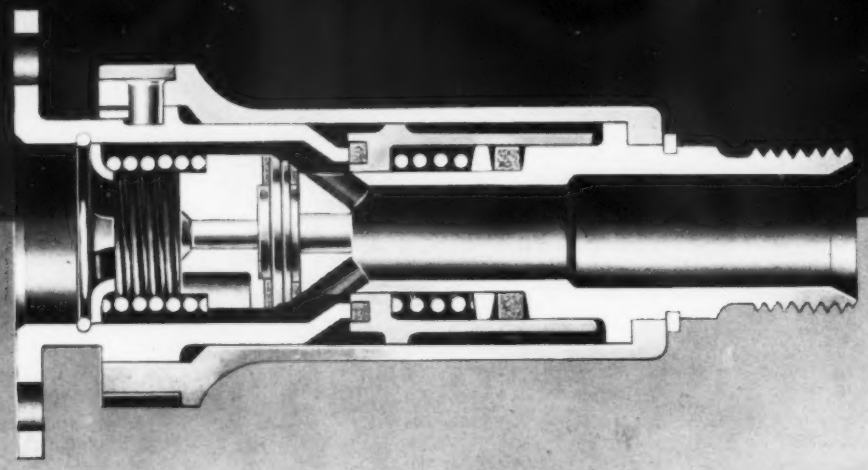
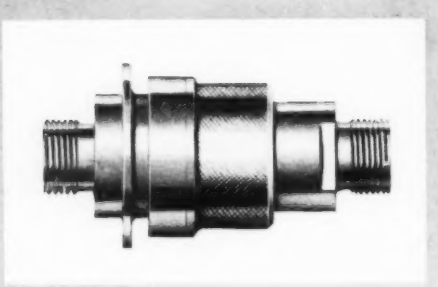
SELF-SEALING



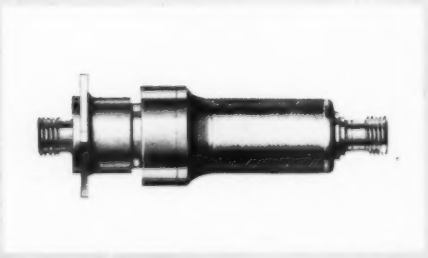
SELF-SEALING COUPLINGS OF BAYONET OR SCREW TYPES

These couplings have been supplied for some considerable time for use with Helium, Heavy Water, etc. and they can be supplied in stainless steel for high temperature conditions up to +180°C. They are completely hermetically self-sealing when disconnected but automatically provide a clear passageway when re-coupled. They are made in a range of sizes from $\frac{1}{4}$" to $\frac{3}{8}$" bore.

Our Technical Staff are always ready to discuss your problems.



Above: a typical Lockheed-Avery coupling in the $\frac{1}{4}$" - $\frac{1}{2}$" range.



Lockheed-Avery coupling in the $\frac{3}{4}$" size. Other variations are also available.

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SIR! LETTERS TO NUCLEAR POWER

The Editor welcomes correspondence for publication

Call for nuclear standards

SIR : For many years now, I have heard that 'nuclear' engineering is really only a form of boiler engineering, with tighter material and inspection specifications applied. While, since the war, British Standard Specifications have been drawn up which reconcile to some extent American petroleum standards, builders of reactors have gone on their own sweet way. Isn't it about time that special nuclear standards were issued, so that design details could be clarified and one could know which authority will be responsible ?

LONDON, NW3 M.T.C. WALLACE

Siting and ships

SIR : Surely it is time that the policy of siting nuclear power stations well away from large towns should be discontinued. How can the public be assured on the one hand that the stations are perfectly safe and on the other that they are too dangerous to build near towns ? Who makes the decision anyway ? Now I see from your previous issues that an atomic-powered merchant ship may be built soon in this country. If reactors can't be allowed near towns how will it ever get into ports ?

SOUTHAMPTON E. DIAPER

►*The decision to locate stations away from towns was taken by the Central Electricity Generating Board on advice from the Atomic Energy Authority and has been recently reaffirmed. See the report on P82 of this issue on the Rome conference for some technological problems which still need to be overcome. The matter of the safety of nuclear powered ships will be worked out at the World Conference on the Safety of Ships at Sea to be held in London next year.*

EDITOR

Old lead preferred?

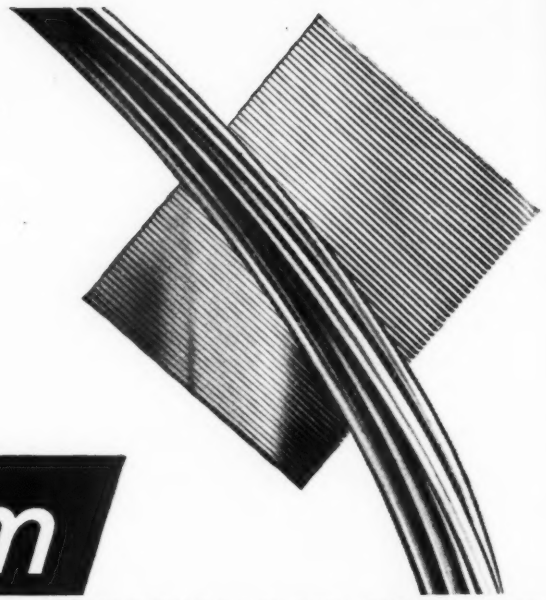
SIR : I have heard recently that all lead used in shielding applications must be many years old because the new metal is slightly radioactive. If this is so, where is it all going to come from ?

Coventry J.E. TRAY

►*It is true that newly-mined lead is slightly radioactive due to the fact that the ore is normally found in rock formations, like granite, which have weak natural radioactivity. However, for almost all shielding applications this doesn't matter and it is only in a few specialized, high efficiency, instruments measuring low intensity radiation that lead over 50 years old must be used. These instruments are fairly uncommon and the supply of lead available from demolition work is more than adequate. - EDITOR*

Zirconium offers a combination of useful properties very attractive to the nuclear engineer.

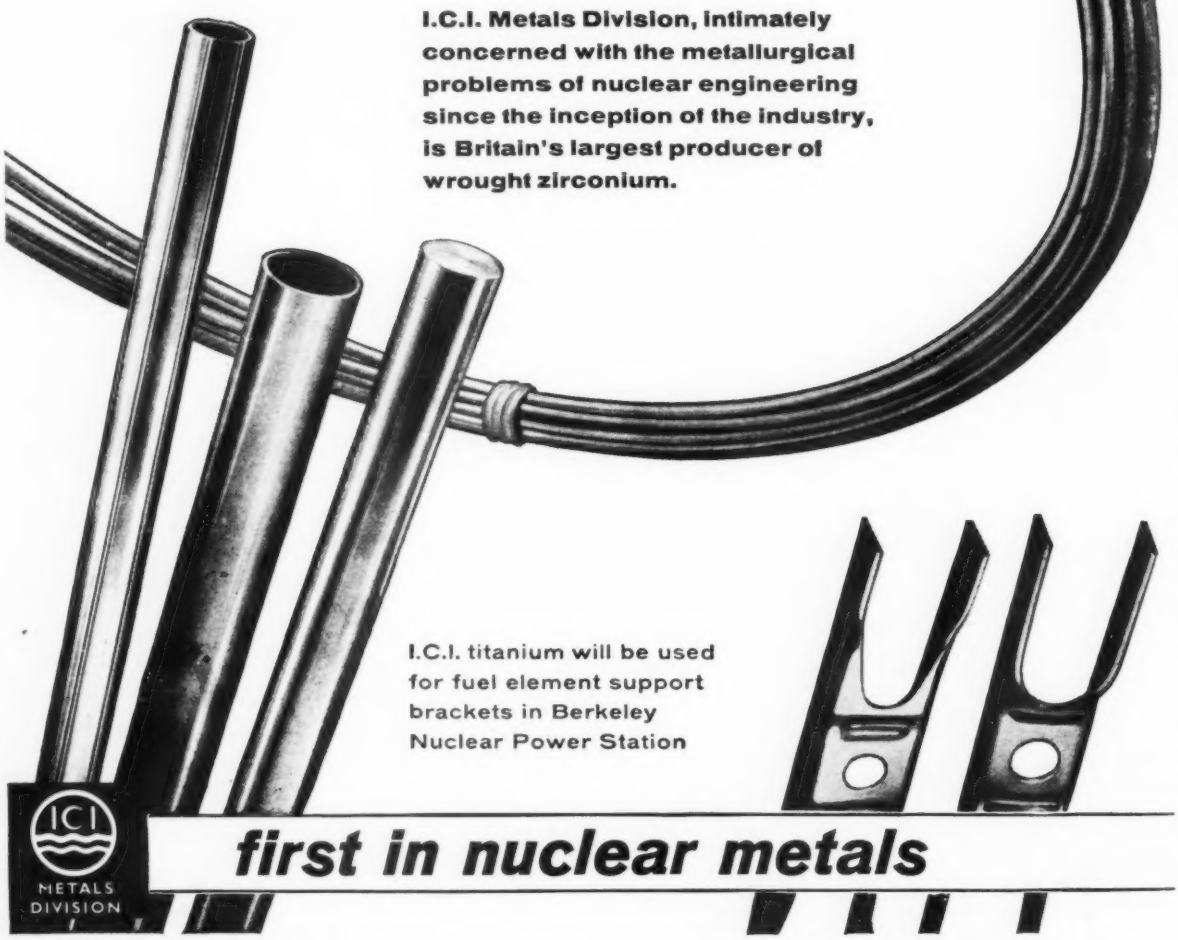
With high mechanical strength, low neutron absorption and good compatibility with uranium as natural assets, zirconium can be alloyed to provide in addition good corrosion resistance to water at high temperatures, or to carbon dioxide.



Zirconium

THE SPECIALIST'S ANSWER TO A SPECIALIST'S PROBLEM

I.C.I. Metals Division, intimately concerned with the metallurgical problems of nuclear engineering since the inception of the industry, is Britain's largest producer of wrought zirconium.



I.C.I. titanium will be used for fuel element support brackets in Berkeley Nuclear Power Station

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Nuclear Power
REACTORS · MATERIALS · INSTRUMENTATION · PROCESSES · IRRADIATION

AUGUST 1959 VOLUME 4 NUMBER 40

Winter frosts

JULY WAS MARKED by several gloomy pronouncements by leaders in the atomic power industry. The general theme is that too little return has been gained for the money and effort expended by the consortia, and that we have reached the point where the market may not be sufficient to support the manufacturing facilities created. At home, owing to the larger nuclear stations now being ordered, only five or six more will be needed to complete the present programme. The successful establishment of a fifth group means that there will simply not be enough business to keep them all going. Also the value of each order is shrinking as technology advances. Overseas the consortia have met stiff competition ; only two orders have been secured after 2 years' hard work, and at least one group has decided that the market for the present type of gas-cooled graphite-moderated reactor is very limited. As this journal has pointed out before, the lack of a clear fuel policy by the Atomic Energy Authority and the non-availability of enriched fuel has made its contribution to the present impasse.

What is to be done ? Discussions in industry have been prolonged and heated. The AEA, a long way behind on its original plans for small scale reactor experiments - not entirely by its own fault - leading to a smaller, more easily exportable unit, and due for an early change to a career diplomat as leader, talks only of 'a period of consolidation' in its annual report. On the Government side the Minister of Power referred in a recent speech to 'winter frosts', which have to be endured (see Worldview). This sounds like very cold comfort for the consortia. Though some of the figures for research expenditure which are unofficially mentioned here and there seem a little exaggerated, there is no doubt that the groups responded magnificently to the original call by the Government, and that they have risked a great deal of money. Now voices have been raised calling for a considerable cut in expenditure. Some of the individual companies on the non-nuclear side would like to break away altogether and take their chances in a system of tendering for the separate components of a nuclear station. The Central Electricity Generating Board is not averse to this. From their point of view it would merely bring the whole set-up into line with practice on conventional stations and might save them some money. They are stepping up their research programme and in a year or two will be in a position to issue the tighter specifications which would be necessary under such a system. But while this may give greater opportunities to the best firms it will not help the main problem, which is the future of the nuclear side of the consortia.

Five teams have been created and they will certainly be needed if the country is eventually to reap the advantages of its early lead in atomic power. The long term opportunities are as good as ever but the present dissatisfaction could lead to a total or partial withdrawal of some companies from the field - just as serious work on the problems of the advanced gas-cooled reactor should be getting under way. Worse, we may see a decrease in the willingness of the best young engineers and physicists to enter or stay in the industry.

Help from the Government in the form of subsidies or a speeding up of the power programme is of course a political decision. So in effect would be more development contracts from the AEA if they were to be meaty enough to make a significant difference. Such decisions will have to be made in the context of a three fuel economy, but they should be made soon.

If it is decided to put no more money in the kitty for the time being industry must be told this and given a lead on how to plan its future. For the consortia merely to go on fighting it out in open competition no longer seems the best plan. It might be advisable to reduce overlapping on research by increasing the proportion done jointly or by agreeing on areas to be handed over to the CEGB. Even some form of collaboration between groups in tendering might be necessary. At the moment there is plenty of discussion but it is taking place round too many tables. More joint talks between all the parties concerned - the Minister of Power, the AEA, the CEGB and all the consortia - are needed and these should be treated as a matter of urgency.

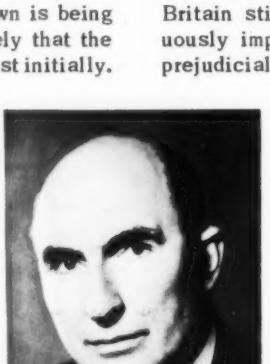
Worldview

the month in atomic energy

Consortia system to go?

Shortly after the Trawsfynydd award, which brought the number of groups actually building nuclear power stations up to five, comes news that the days of the whole consortia system may be numbered. The Central Electricity Generating Board is now considering an end to the practice of ordering complete stations on a turnkey basis. Some member companies of the consortia have pressed for a system of separate contracts for the various components and the CEGB itself would prefer this. How far the orders could be broken down is being actively discussed but it seems very unlikely that the cores and boilers would be separated, at least initially. The changeover would take some time and two more stations at least will probably be ordered under the present practice ; tenders for the next one, at Dungeness, will be going in from the consortia over the next few weeks.

The new scheme would necessitate much more research by the CEGB, who have so far left design almost entirely to the consortia. They would have to lay down standards and impose narrower limits in specifications - pressure vessels, for example, vary widely in shape at present. In this connexion it is interesting to note that the CEGB will have spent £M1 on building nuclear development and research laboratories at Berkeley by this time next year. Present plans envisage expenditure of another £M½ in the following year, and their contribution to research should amount to about 10% of the AEA's by the end of 1961.



SIR ROGER MAKINS

A distinguished career in diplomacy . . .

. . . but Nelson urges less competition

The early atmosphere of optimism in the atomic energy industry has now vanished, according to Mr. H.G. Nelson, managing director of English Electric. Speaking at the official opening of the company's Atomic Power Centre at Whetstone on July 24 he said that the volume of nuclear power station business may be too small to support the facilities which have been established. This was because the availability of oil and coal is much more secure and because the rapid growth in size and efficiency of both atomic and conventional stations reduces the number that needs to be built to meet the country's power demands. In addition it now seemed that it will be longer before atomic energy can compete economically with other forms of power. For these reasons the export market might be slower to develop than was at first thought. 'We had at one time great hopes than an export market would open up before us, but it has proved very competitive' he said. 'The whole situation is a difficult one which is giving rise to serious concern, and I don't know what will happen. Under the circumstances competition between the groups, instead of being the healthy stimulus it has been in the past, is in danger of becoming an aggravation of a very serious position.'

In reply the Minister of Power, Lord Mills, stressed that atomic energy still offers bright prospects and Britain still leads the world with five groups continuously improving technology. 'Any reversal would be prejudicial to industry,' he thought. 'There are always those who change with every change in the weather. Remember every summer gives way to the frost of winter. If a farmer says it takes a frost to clear the air he speaks from experience. The inviting days are at an end and we now need strength to work through winter to the spring.'

AEA gets new chief

On July 21, the Prime Minister appointed Sir Roger Makins, GCMG, KCB, as the new chairman of the UK Atomic Energy Authority. At present, Sir Roger is Joint Permanent Secretary to the Treasury and he will take up his new duties at the end of the year ; he takes over from Lord Plowden, KCB, KBE, who will be relinquishing this appointment to become the chairman of the British Aluminium and vice-chairman of Tube Investments, as well as 'taking general charge' of the Government's internal review of the executive's control of public spending.

After seventeen years in various Foreign Office appointments, Sir Roger, who is 55 was Minister at Washington from 1945 to 1947. He returned to the F.O. for five years as Assistant Under-Secretary of State and later became Deputy Under-Secretary of State. At the end of 1952, Sir Roger went to Washington again, where he remained until July, 1956, as Ambassador Extraordinary Plenipotentiary. He assumed his present duties on July 19, 1956, when he was charged with the financial and economic work of the Treasury and has been Chairman of the Economic Planning Board since 1956. This is the second senior job to go to a civil servant - Sir Alan Hitchman was appointed in April (see 'Worldview' - March).

Worldview

Nuclear licensing comes to the UK

The Nuclear Installations (Licensing and Insurance) Act received Royal Assent on July 9. Under this law, the construction and operation of reactors and any other nuclear installations which may be prescribed by regulations will have to have a licence from the Ministry of Power, who may impose such safety conditions as necessary. Every licensee will have to insure his liability or show that adequate liquid assets are held ; the liability is limited in effect to £M5 in respect of any one incident - the chance of damage ever approaching this figure is regarded as extremely remote. Actions for damage may be instituted up to thirty years after the occurrence, but claims presented after ten years will be uninsured risks and the Act provides for Parliament to determine how they are to be met.

The AEA's liability was already similar to that of the licensees under the Act, but without limit of amount. The Act now extends the Authority's liability to cover irradiated fuel in the course of carriage and applies the thirty-year period of limitation to actions against them. The licensing provisions of the Bill do not extend to either the AEA or any Government Department operating a nuclear installation.

To implement this Act, the Ministry of Power is setting up an Inspectorate of Nuclear Installations, of which the first Chief Inspector is to be Major-General S.W. Joslin.

ICSE to replace Zeta

When the AEA's Annual Report was released on July 22, Sir William Penney stated that to obtain 'a more basic approach to controlled thermonuclear reactions' a new facility, the Intermediate Current Stability Experiment, ICSE, was to be built. While the design has not yet been finalized, it has been established that it will be of the torus type ; to give stable plasma and eliminate the various forms of instability experienced with Zeta and other existing forms of CTRs, there will be an elaborate arrangement of magnetic fields and a fast instead of a slow pinch will be achieved. With ICSE, which is expected to be running in 2 - 3 years, it is hoped that the theoretical criteria of stability will be achieved.

Location of fifth station decided

In the House of Commons, on July 13, in a written reply, it was announced that Lord Mills, the Minister of Power, had given consent to the CEGB to build their fifth nuclear power station at Dungeness (an aerial picture of the site appeared in 'Worldview', June 1958).

Latin America to get advice

VIENNA - In response to requests from Argentina, Brazil and Venezuela an eight-man IAEA team, led by Edward R. Trapnell, Special Assistant to the Director General, will visit Latin America to advise on development. (See 'Worldview', June, 1959). Argentina is particularly interested in prospecting for uranium ores and their mining and processing ; Brazil wants to review its expanding atomic programme and to assist Brazil, UNESCO has voted to help in the reconstruction of the Brazilian Centre of Physics Research recently gutted by fire ; and Venezuela wishes to develop

The sign above Britain's only privately-owned reactor lights up for the first time as it goes into operation at the AEI laboratories at Aldermaston. Moderated and cooled by light water and fuelled with 90% enriched uranium plates clad in aluminium, it has a maximum power of 5MW, and will be used for general research on power reactor development. Overseas countries are interested and already one has been ordered for West Germany.

a research programme for its reactor and establish an atomic energy commission.

More marine projects

BRUSSELS - At the beginning of July, Euratom decided to set up special working groups to study the technical and economic aspects of nuclear powered ships ; the possibility of collaboration with non-member countries in this field is also to be studied to prevent duplication of effort.

ROME - The Defence Minister announced in the Senate on July 2 that the Italian Navy is to build a nuclear-powered submarine. The reactor and hull are to be built in Italy and it is proposed to include this vessel in the second stage of the programme of construction now in hand,

Joint programme deferred

BRUSSELS - At the request of the President of Euratom, the United States AEC have agreed to extending from September 1 to October 20, the deadline for nuclear power proposals under the US-Euratom joint programme. This deferment will not affect the completion date for the selected projects, which remains December 31, 1963.

First loan of heavy water

AIKEN, South Carolina - The AEC and the Indian Government have signed a contract for the lease of 15 tons of heavy water as the initial supply for a Zero Energy Research Reactor at Trombay, India. This is the first time the Commission has leased heavy water to a foreign government.

Euratom takes over Ispra

ROME - On July 22 an agreement was signed by Euratom and the Italian Government whereby the Ispra Centre is to be gradually transferred to the Commission. In the transition period, priority will be given to the current programme of the CNRN. Under the agreement, Euratom will contribute $M24 for equipment and facilities, with the Italian Government providing up to $M9 for the construction of necessary buildings and a European School.

AEC goes South

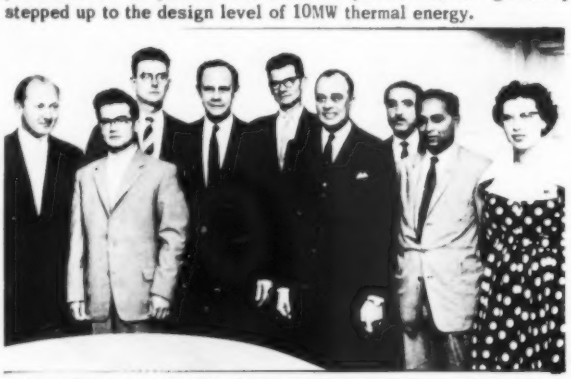
PANAMA - An agreement has been signed by the US State Department, the AEC and the Government here, covering cooperation

in atomic research. Through this, the Panamanian Government receives reactor know-how and the American nuclear industry is given the go-ahead to supply equipment. Up to 6kg of U-235 in uranium enriched up to a maximum of 20% U-235 may be leased by AEC, plus an additional quantity as the American Commission considers necessary to permit continuous operation of any reactors while replaced elements are cooling or in transit.

ENEA reactor achieves criticality

HALDEN, near Oslo - The boiling water reactor of the Norwegian Institute for Atomic Energy here went critical on June 29. This project is sponsored by the European Nuclear Energy Agency (ENEA) of OEEC. It is the first boiling heavy water reactor and the first BWR in Europe.

The reactor, moderated and cooled by heavy water, uses natural uranium and is located in rock near the paper and pulp factory Saugbrugsforeningen in Halden. In addition to functioning as a demonstration unit for this type of reactor, some 15 tons per hour of process steam will be produced in the secondary light water circuit, which will eventually be used in the paper factory. The total cost of the plant, including heavy water, from the US, and the first uranium fuel load, from the UK, was some 28 million crowns (£M1¼). During the next six months, the unit will be operated at low power levels to enable fundamental reactor physics experiments to be performed ; then the power will be gradually stepped up to the design level of 10MW thermal energy.



The Chairman of IAEA Board of Governors meets the team to go to South America. Lt. to rt. Mr. R. Hofer (Austria), Mr. V. Shmelev (IAEA), Mr. A. Gerstner (France), Mr. E. Trapnell (IAEA, leader), Mr. A. Schuffelen (Netherlands), Mr. C. Bernardes, Chairman, IAEA Board of Governors, Mr. J. Catala (IAEA), Mr. S. Dhar (IAEA) and Miss H. Jacobsen (IAEA). Mr. D. Maxwell (South Africa), the eighth member of the team, will join it later

CANDU takes shape

OTTAWA - On June 18, the Minister of Trade, Mr. Gordon Churchill, announced that Atomic Energy of Canada Ltd. is to begin immediately on the final design and to plan the early construction of a 200MW nuclear power station. Known as CANDU (Canadian Deuterium Uranium), it will use a natural uranium-heavy water system and is estimated to cost some $M60, exclusive of design and development costs. It is scheduled to come into operation late 1964 or early 1965.

Ontario Hydro will provide the site, yet to be chosen, give substantial support in the design of the CANDU station, co-operate in its construction and operate it as a unit in the Ontario Hydro's power distribution network. The power company will purchase the plant when it has demonstrated that it has suitable characteristics for incorporation into the existing system - the purchase price formula will be such that the output from the CANDU station is competitive with the cost of power from modern coal-fired power plants of similar size.

Portugese start planning

LISBON - During June and July, a team of engineers from the Companhia Portuguesa de Industrias Nucleares, CPIN, visited French nuclear installations and held discussions with consultants and contractors. As Portugal will need to install about 2000MW of electrical generating capacity between 1970 and 1980, CPIN has recommended that a 30 - 50MW pilot plant is built in 1965/67 and a prototype power station, of approximately 150MW is started in 1970/71.

WTR goes critical

WALTZ MILL, Pa. - The new Westinghouse Testing Reactor, WTR, using highly enriched uranium fuel and water as moderator and coolant, went critical on June 30. Initial operations will be with a power level of 20MW(thermal) but the plant has been built so that eventually the power can be increased up to 60MW(thermal). The primary purpose of this reactor is test materials and fuels for nuclear power stations.

Operation Sunrise progresses

NEW YORK - General Electric has been selected by Consumers Power Company to furnish the nuclear portion of a power station to be built at Big Rock Point, on Lake Michigan, midway between Charlevoix and Petoskey. The reactor will be a direct cycle, forced circulation, boiling water unit and will have as its primary objective, the development of engineering and economic data on high power density and high specific power. It is the second of five key development BWRs for the 'Operation Sunrise' programme.

The plant, including the conventional power generating equipment, will be engineered and constructed by the Bechtel Corp., as the main contractors, with GE supplying the reactor, instrumentation, fuel and generating equipment. When the unit first goes into operation, scheduled for 1962, the net electrical output will be 50MW, but Consumers Power in cooperation with GE, plan an extensive research and development programme with the object of increasing the output to 75MW by 1966/8. The reactor, contained in a sealed capsule 151 ft high and 90 ft in diameter, with external steam separation, will operate at a pressure of from 1000 to 1450 lb/sq.in. During the developmental period, the fuel will be zircaloy-clad slightly enriched uranium pellets. The estimated cost is $M30 some $M10 more than that for a conventional generating station of similar capacity.

The aim of 'Operation Sunrise' is to develop design and construction enabling single unit plants of 200 to 300MW to be built at capital costs of between £80 and £90 per kilowatt, which represents an extension of the upper practical rating of about 100MW, with a reduction of some £36 a kilowatt in capital costs.

AEC drops NDCA Project

WASHINGTON Work being undertaken by the Nuclear Development Corporation of America in connexion with the 10MW liquid sodium-cooled, heavy water-moderated reactor power conception at Anchorage, Alaska, has been suspended by the AEC. Over the two years since this project was started it has become increasingly apparent that, technically, it would not be sound policy to build at a remote non-Commission site, a design that was not yet proven.

Record steam heat by SRE

CANOGA PARK, Calif. - The highest steam temperature so far produced by heat from a reactor was achieved by Atomics International Sodium Reactor Experiment (SRE) during June, when superheated steam at 1000° F was generated. The heat transfer medium, molten sodium, reached a temperature of 1060° F during the record power run. During the two years this unit has been operating, it has provided steam for the production of over 15,355,000 kilowatt hours of electricity by the Southern California Edison Company's plant adjacent to the reactor.

Progress in Superheat development

WASHINGTON, DC Two companies have been awarded cost plus fixed fee type contracts, totalling some $M4 for work on AEC's nuclear superheat development programme. One contract, with Combustion Engineering-General Nuclear Engineering Corp. is applicable to integral boiling superheated reactors ; and the second contract, with General Electric, relates mainly to separate superheaters.

Two marine firsts in US

QUINCY, Mass - On July 14, the US Navy's first nuclear-powered surface vessel, Hull No. 1169, a heavy cruiser, was launched and formally, named 'Long Beach'. This ship will be powered by two PWRs. The first American nuclear-powered destroyer, the 'Bainbridge', is also under construction in the same yards.

CAMDEN, New Jersey - 'Savannah', the world's first nuclear-powered passenger-cargo ship, was launched here on July 21 by Mrs. Eisenhower. This 21,000 ton vessel is now some 70% complete and will have cost over $M40 when finished.

UKAEA ANNUAL REVIEW

On July 22, the Fifth Annual Report of the AEA for the year 1958/59 was issued. According to the Chairman, Lord Plowden, the organization is now entering 'a period of consolidation'. This is reflected by the fact that while the total staff has increased from just over 30,000 last year to more than 35,000 now, the Authority's Estimates, at a net total of £92,433,010 for 1959/60, are decreased by £13,390,010 compared with last year's figure.

Reactors

Work on the advanced gas-cooled reactor, AGR, has started, and designs for the Dragon project high-temperature gas-cooled reactor, HTGC, are in hand and construction should start later this year. The study of gas-cooled, heavy water-moderated reactor systems has reached the stage of detailed design. While no decision to build has yet been made, the AEA are investigating a 100MWt experimental Steam-Cooled Heavy Water Reactor, SCHWR, which could be brought into operation by the end of 1962 and modified to generate electricity. All these reactors employ enriched uranium and attempts are being made to reduce by as much as possible the amount of such enrichment compatible with efficiency, to keep the costs at an acceptable level - while 1.5% enrichment is considered too expensive, between 1 and 1.2% is acceptable.

Behind this work is the aim to develop technology to a point where smaller reactors, 20 - 100MW, will be competitive in the field of electrical power generation. A certain amount of work has been carried out but the AEA admits it is not yet in a position to make any firm recommendations.

Originally the Authority's AGR had been included in the design studies submitted to the Galbraith Committee as a possible marine propulsion unit, but after further consideration it was withdrawn as being too large and too costly for the purpose.

Progress has continued with the Harwell experimental reactors and Pluto has been increased in power from 10 to 15 MWt ; new hollow fuel elements have been successfully used in both Dido and Pluto reactors. Delayed by diversion of technical staff to help with extra work arising from the Windscale incident, the fast breeder reactor at Dounreay is now expected to go critical during August and its power will be steadily stepped up until a level of 12-15MW is reached between April and June next year.

CTR progresses

The AEA have decided that controlled thermonuclear research will not be moved to Winfrith but, as yet, no decision has been made on its eventual location. Over the past year, Zeta has been modified and its current stepped up, but work on this unit is slowing down and is not expected to continue for much longer than another year. At Aldermaston, a small mirror-type machine is being employed, but the overall findings on CTR to date indicate that a more basic approach must be made. For this a new facility, Intermediate Current Stability Experiment, ICSE (see this month's 'Worldview') is to be built at the new site.

Fuels

During the year under review, the Operations Branch increased its output by more than 50% and by January, 1959, the millionth fuel rod had been produced at Springfields, where new processing facilities were brought into use.

As the uranium contracts expire between 1962 and 1967, both the AEA and the CEGB expect that an excess of uranium will bring about a reduction in price. On present figures, a modern coal-fired station can produce power for between 0·5d and 0·65d per unit, depending upon location, with nuclear power costing up to 0·7d per unit ; by 1967/70, the nuclear costs should be reduced to the lower range of current coal prices.

AEA's evidence is that Beryllium will prove satisfactory as a canning material. To achieve maximum economy, studies are being made on the use of plutonium, especially in ceramic forms, and comparative cost assessments between slightly enriched uranium in 'slow' reactors and plutonium in 'fast' reactors.

Radioisotopes

Sales of isotopes manufactured by the Authority increased from £650,000 in 1957/58 to £800,000 in 1958/59, of which 60% were exported to fifty-five countries. A new irradiation service is provided by the Wantage Radiation Laboratories, utilizing spent fuel elements. Already 20 miles of polythene tubing has been treated to increase its heat-resisting properties and many items of hospital equipment, including blankets, have been sterilized.

Changes in organization

The Industrial Group has been divided into two new groups - 'Development and Engineering' and 'Production'.

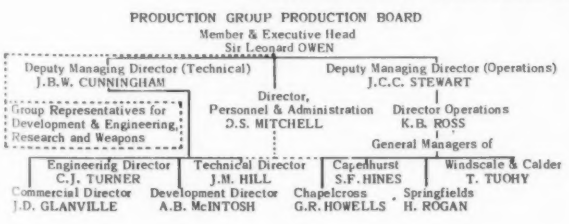
THE DEVELOPMENT AND ENGINEERING GROUP takes over the Risley Project and Service Design Offices ; the Supply Services, except for chemicals, graphite and fuel element components ; the Engineering Section of the Industrial Power Branch, for design, consultancy and technical collaboration ; the Research and Development Branch Headquarters ; the Works at Dounreay and Culcheth and the R & D laboratories at Works, except those for operating processes. The PRODUCTION GROUP absorbs the Commercial Section of the Industrial Power Branch, except for patents and licensing arrangements ; the Operations Branch Headquarters ; the Works at Chapelcross, Capenhurst, Springfields, Windscale and Calder and the R & D laboratories at Works, concerned with operating processes ; Supply Services for purchasing chemicals, graphite and fuel element components. In addition, design offices will be set up at Works to carry out capital projects up to £50,000 in value, and a Fuel Element Inspectorate will be set up at Springfields.

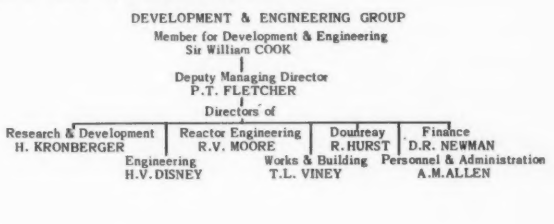
The Technical Policy, the Personnel and Administrative and the Finance and Accounts Branches, with that part of the Commercial Section dealing with patents and licensing arrangements, will be divided between the two new groups. The Boards of Management of the two groups are shown below.

With effect from July 1, a new Branch, replacing the separate Group headquarters' health and safety organizations, has been set up under the control of the Director of Health and Safety, Dr. A.S. McLean. The technical work of the new branch will be carried out by the Safeguards Division, located at Risley for the safety of reactors, plant and laboratories, and the Radiological Protection Division, located at Harwell ; associated with these two technical divisions will be an Administrative Division.

The Authority has also, from July 1, restored to their technical Members executive as well as functional responsibility. 'Experience has shown that the separation of these responsibilities does not suit the particular circumstances of the AEA' they say.

BOARDS OF MANAGEMENT OF NEW GROUPS





NUCLEAR SHIPS — three approaches

With the aid of hitherto unpublished details and working drawings supplied by three of the British companies who are interested in developing a reactor for ship propulsion (Worldview, June) Nuclear Power has prepared the following drawings and descriptions as a handy reference for these three widely differing types.

PRESSURIZED WATER REACTOR

Basically this Babcock and Wilcox design is similar to the one made by the American B & W for the merchant ship N.S. 'Savannah' which was launched on July 21 and should be fully operational in a year's time. Development by the British company has resulted in a power output 2½ times as great (180MW to 'Savannah's' 64) with only a 20% increase in size and none in weight. B & W state that a plant with guaranteed output could be at sea by the end of 1962

Providing the necessary facilities for fuel element manufacture eventually become available in this country, estimated cost is between 0·3 and 0·6 d/s.h.p.h. depending on the type. Two alternative fuel element designs are envisaged - uranium oxide pellets clad in either stainless steel or zirconium. With the former, enrichment would be 4% and estimated burnup 5500MWd/t; with the latter the figures would be 2% and 11,000. This is higher than the 'Savannah' design.

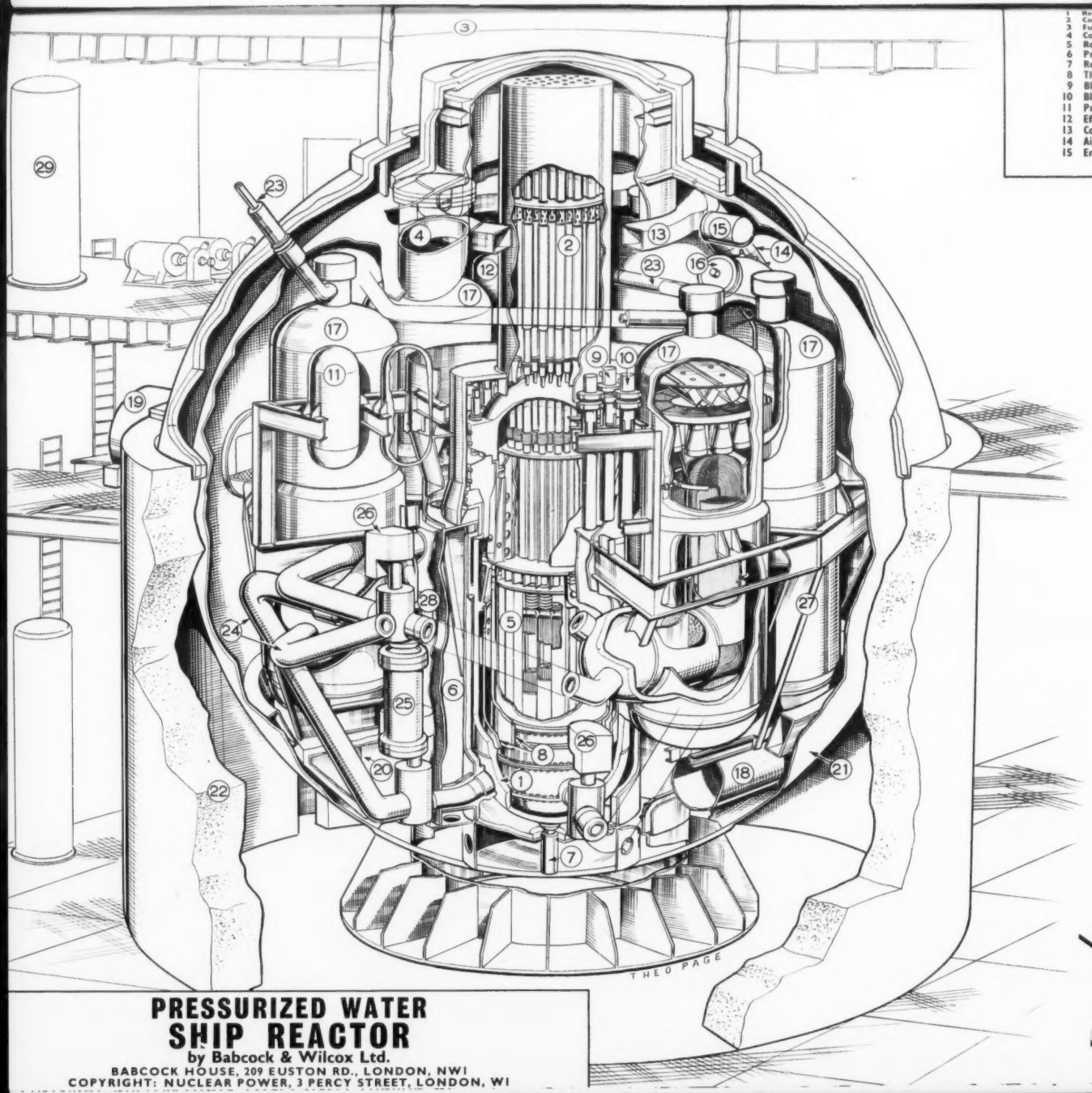
Reactor history

The application of PWR's for marine purposes was started in 1952 by Westinghouse with the Carrier Vessel Reactor project study, CVR, for the US Navy. Leading to submarine reactor units was the STR Mark 1 land-based prototype and the first sea-going reactor was in the USS 'Nautilus', completed on September 30, 1954. Large power production was achieved with the Shippingport, Pa, project in 1957 and by July this year, the NS 'Savannah', a passenger/cargo vessel with a Babcock & Wilcox PWR and the USS 'Long Beach', a heavy cruiser, had been launched. Ten marine PWR's are now operating and by 1961, thirty-six such reactors will have been completed and operating in the US Navy. In the USSR the 'Lenin' icebreaker is nearing completion. The British Babcock & Wilcox has a technical exchange agreement with the US firm, but actual building of a ship reactor would be carried out here.

Another interesting design change is the choice of a spherical pressure vessel instead of the 'Savannah's' cylinder and a reduction in thickness - 2in. as against $2\frac{3}{8}$-4in. Operating pressure is the same in both. Fuel loading is increased by 2 tonnes although the core diameter is only 4in. larger and the active height remains the same. Overall coolant temperature rise is doubled, steam consumption increased by a factor of 2½ and shaft horsepower by over 3.

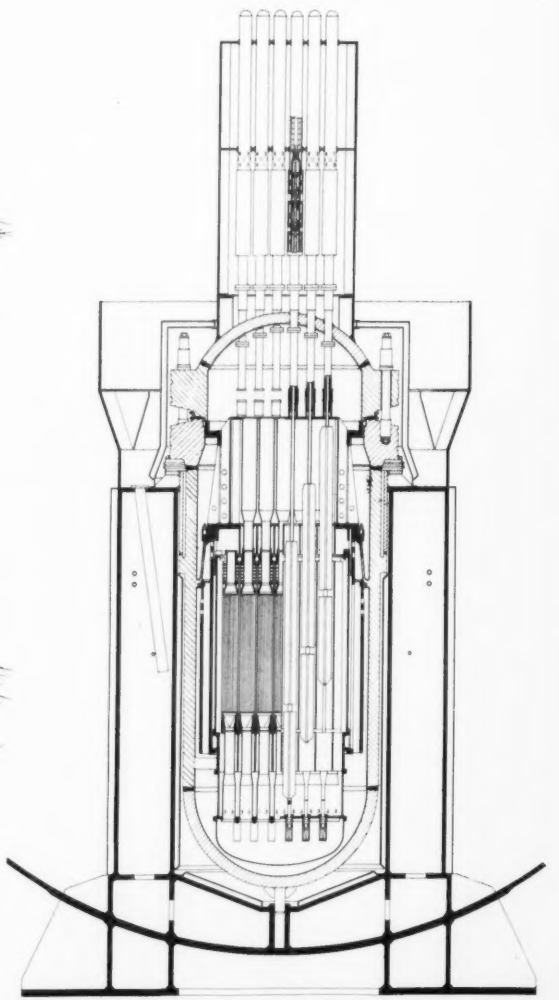
Main design parameters

PERFORMANCE	
net output	65,000 s.h.p.
reactor heat output	180MW
wt. of complete plant	3000 tons
CONTAINMENT	
spherical, dia.	42ft 6in.
thickness	approx 2in.
REACTOR CORE	
diameter	5ft 6in.
active height	5ft 6in.
CONTROL	
material	boron steel
shim rods manual	12
servo rods, manual or automatic	12
automatic control ensures reactor power and maintains primary coolant at 500° F average	
FUEL	
material	UO_2 pellets
UO_2 pellet dia.	7/16in. approx.
no. of fuel element assemblies	37, each of 220 rods
canning	s.s. or Zr
enrichment	4% with s.s. 2% with Zr
fuel charge	9 tonnes (approx.)
endurance	500 days seagoing service at full power
eventual cost	0·3 - 0·6 d/s.h.p./h
average rating	20MW/tonne
burnup - s.s. core	5500MWd/t approx.
- Zr core	11,000MWd/t approx.
MODERATOR AND COOLANT	
type	H_2O
average coolant pressure	1750 lb/sq.in.
inlet temp.	248° C
outlet temp.	272° C
pressure drop overall	60 lb/sq.in. approx.
pumping power	1800 h.p.
flow	12 million lb/h
STEAM	
pressure (sat.)	410 lb/sq.in.
temp.	447° F
evaporation	616,000 lb/h



1 Reactor vessel
2 Control rod drives
3 Fuel handling access trunk
4 Containment access
5 Reactor core
6 Primary shield tank
7 Reactor vessel location spigot
8 Thermal shields
9 Blowdown coolers
10 Blowdown regenerators
11 Primary loop purification ion exchangers
12 Effluent condensing tank
13 Containment air conditioning ducting
14 Air conditioning fans
15 Emergency make-up tank
16 Pressurizer
17 Heat exchangers
18 Containment drain tank
19 Air lock
20 High activity storage tank
21 Containment compartment (42' 6" dia)
22 Biological shield
23 Main steam outlet pipes
24 Primary piping
25 Circulating pumps motor
26 Gate valve
27 Steel support structure
28 Circulating pump
29 Make-up ion exchangers

SECTION THROUGH CORE



PRESSURIZED WATER SHIP REACTOR

by Babcock & Wilcox Ltd.

BABCOCK HOUSE, 209 EUSTON RD., LONDON, NW1

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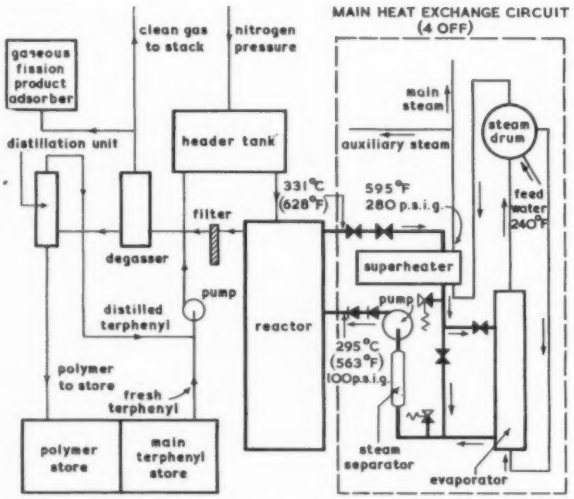
ORGANIC MODERATED REACTOR

This reactor, designed by Hawker Siddeley Nuclear Power Co.Ltd., uses slightly enriched uranium dioxide fuel elements canned in stainless steel. Terphenyl is employed for both moderator and coolant and each fuel element bundle is separated into zones by a barrier tube. Mild steel would be used in the construction of the reactor vessel and primary circuit, and with the low system pressure involved a thickness of less than one inch is envisaged.

Detailed studies of the OMR have been made on Hawker Siddeley's analogue computer installation to show that it has a negative temperature coefficient under all burnup conditions. Main snag of this type of reactor is radiation damage to the moderator/coolant. Much work remains to be done on this but in the meantime Hawker Siddeley have allowed a cost of replenishment of 0·07d a shaft horsepower-hour and expect this to fall with increasing production of terphenyl. It is proposed to counter any fire hazard by using nitrogen-rich air in the reactor compartment. Fuel elements are made up of two sections to allow for end to end fuel cycling which could be arranged at intervals of one to two years to suit the operator. Future possibilities include beryllium canning, the use of plutonium enrichment, and a two-zone core. Coolant passed through the outer lower flux zone would be raised to a higher temperature than the rest and passed to a superheater. The company estimates that steam conditions of 710°F and 480lb/sq.in. and a cycle efficiency of 24·8% could be obtained with this arrangement, resulting in a 9% reduction of fuel costs for an increase of only 2% in terphenyl replacement costs. Higher heat transfer rates, possibly up to nucleate boiling, are also considered feasible, giving a 60% increase in output for a given size.

Reactor history

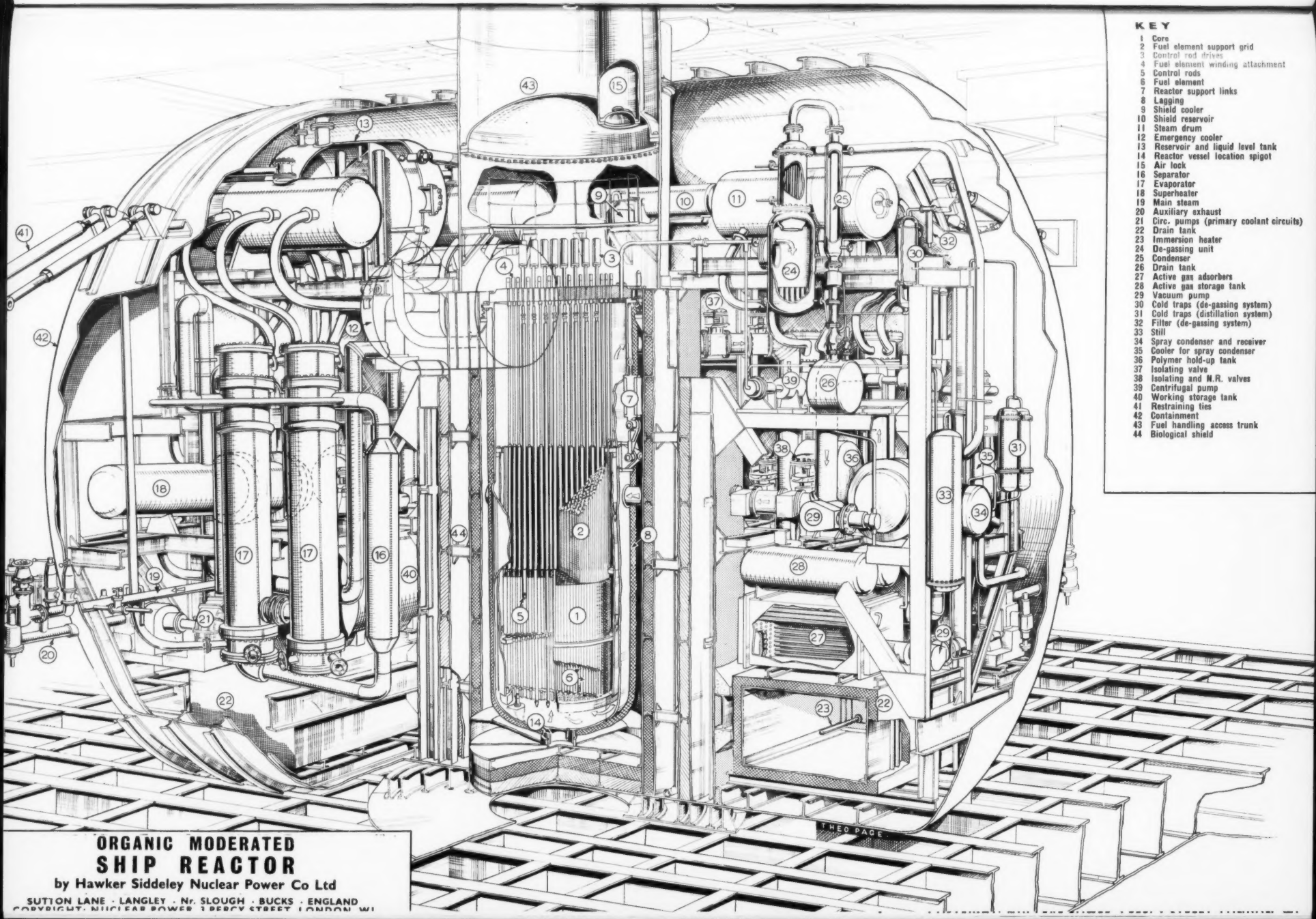
Early work on organic liquid cooled and moderated reactor systems was initiated by Atomics International and resulted in the OMRE being built at Idaho for the American AEC in 1957. From this experimental reactor, both land and marine power projects have been started. Building of the Piqua, Ohio, power station has begun and in March, 1959, Interatom, formed by Demag and Atomics International, started detailed work on an OMR for a 40,000 ton tanker. At the end of last June, a design project for a 60,000 ton deadweight tanker was completed by AI for the AEC.



Flow sheet for terphenyl circuits

Main design parameters

PERFORMANCE	
net output	50,000 s.h.p.
reactor heat output	173 MW
cost of complete installation including development charges	£1,500,000
wt. of complete plant	2060 tons
CONTAINMENT	
diameter	44ft
overall length	60ft
REACTOR CORE	
diameter	8ft 3in.
height	6ft 6in.
FUEL	
material	UO_2
enrichment	0·4% (2 C)
no. of fuel element assemblies	650 (approx.) each of 19 rods
channel diameter	3in.
channel pitch	3·44in.
canning	s.s.
fuel charge	22·9 tonnes
average rating	7·5 MW/tonne
average burnup	10,000 MWd/tonne
MODERATOR AND COOLANT	
type	terphenyl + 30% polymer
max. operating pressure	100 lb/sq.in.g.
max. flow	30,500 gal/min
circuit pressure drop	60 lb/sq.in.
total pumping power	1640 b.h.p. at turbine coupling
reactor inlet temp.	295°C
reactor outlet temp.	331°C
cost of coolant make-up	0·07 d/s.h.p/h
SECONDARY CIRCUIT	
total evaporation	534,400 lb/h
superheater outlet press	295 lb/sq.in. abs.
" outlet temp.	595° F



ORGANIC MODERATED
SHIP REACTOR
by Hawker Siddeley Nuclear Power Co Ltd

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STEAM COOLED HEAVY WATER MODERATED REACTOR

Fuelled by slightly enriched uranium oxide pellets in stainless steel cans, this Vickers Nuclear Engineering pressure tube design employs heavy water as moderator and a closed primary coolant circuit of steam with thermocompressor self-circulation and a separate steam circuit to drive the turbines. Control is by level changes of moderator, and the reactor is scrammed by opening valves to let the moderator run out of the control tubes under gravity. Main future possibilities : beryllium canning, plutonium enrichment and open cycle operation.

Main design parameters

PERFORMANCE

net output	50,000 s.h.p.
reactor heat output (nominal)	150MW
at full main engine power	160.5MW
at half main engine power	82.5MW
core life, full power	75,563MWd
half power	76,656MWd
wt. of complete plant	2100 tons

REACTOR CORE

diameter	10ft
height	10ft
calandria tank inside dia.	10ft 4 in.
inside height	10ft 8 in.
no. of fuel channels	186
lattice pitch	8 in. triangular
calandria tube	Al alloy, $3\frac{5}{8}$ in. i.d. by $\frac{1}{8}$ in. thick
fuel channel barrier tube	s.s., 3·1 in. i.d. by 0·015in. thick
no. of moderator removal tubes	147
moderator removal tube	Al, 5·06 i.d. by 0·030in. thick
heat barrier gas	helium

REFLECTOR

radial D_2O (nominal)	2in.	axial D_2O (nominal)		6in.
" H_2O	6in.	" H_2O (combined with structure cooling)		nominal

FUEL

material	UO_2 pellets
density	10g/cc
U-235 content	approx. 1·7%
no. of fuel rods per element assembly	19
UO_2 pellet dia.	0·50in.
length	0·75in.
canning material	s.s.
" thickness	0·010in.
active fuel rod length	10ft
wt. of UO_2 per element assembly	162lb
total wt. of UO_2	13·6 tonnes
wt. of fuel element assembly (including standpipe plug)	200lb
fuel element max. surface temp.	680° C
" " " centre temp.	1700° C

MODERATOR

type	D_2O
quantity in tank (control tubes full)	50,000lb
quantity in external circuit	5000lb (estimated)
heat production in moderator	10·5MW
moderator circulation rate	138lb/s
reactor temp., inlet	50° C
outlet	90° C

REACTOR COOLANT

type	steam (H_2O)
mean steam pressure	600 lb/sq.in.abs.
pressure drop in coolant channel	20 lb/sq.in.
reactor total steam flow	$1·74 \times 10^6$ lb/h
reactor coolant inlet temp.	260° C
" " outlet temp.	520° C
max. channel steam velocity	180 ft/s

PRIMARY STEAM CIRCUIT

circulators	2 thermocompressors
thermocompressor nozzle steam	1800 lb/sq.in.abs., 650° F
each thermocompressor nozzle steam flow	212,300 lb/h
each thermocompressor suction steam flow	657,820 lb/h
thermocompressor suction steam	570 lb/sq.in., 496° F
thermocompressor discharge steam	640 lb/sq.in.abs.(approx) 500°F
feed pump	2, 100% turbine driven
auxiliary feed pumps (capacity 7% approx.)	2, electrically driven
steam flow to secondary steam generators	2,212,300
minimum feedwater pressure (on feed pump suction)	525 lb/sq.in.abs.
live steam feed heaters	
feed inlet temp.	340° F) normal
feed outlet temp.	350° F)

SECONDARY STEAM CIRCUIT

pressure	420 lb/sq.in.abs.
temp.	850° F
flow	2,212,400

Physics for Hot Clean Core

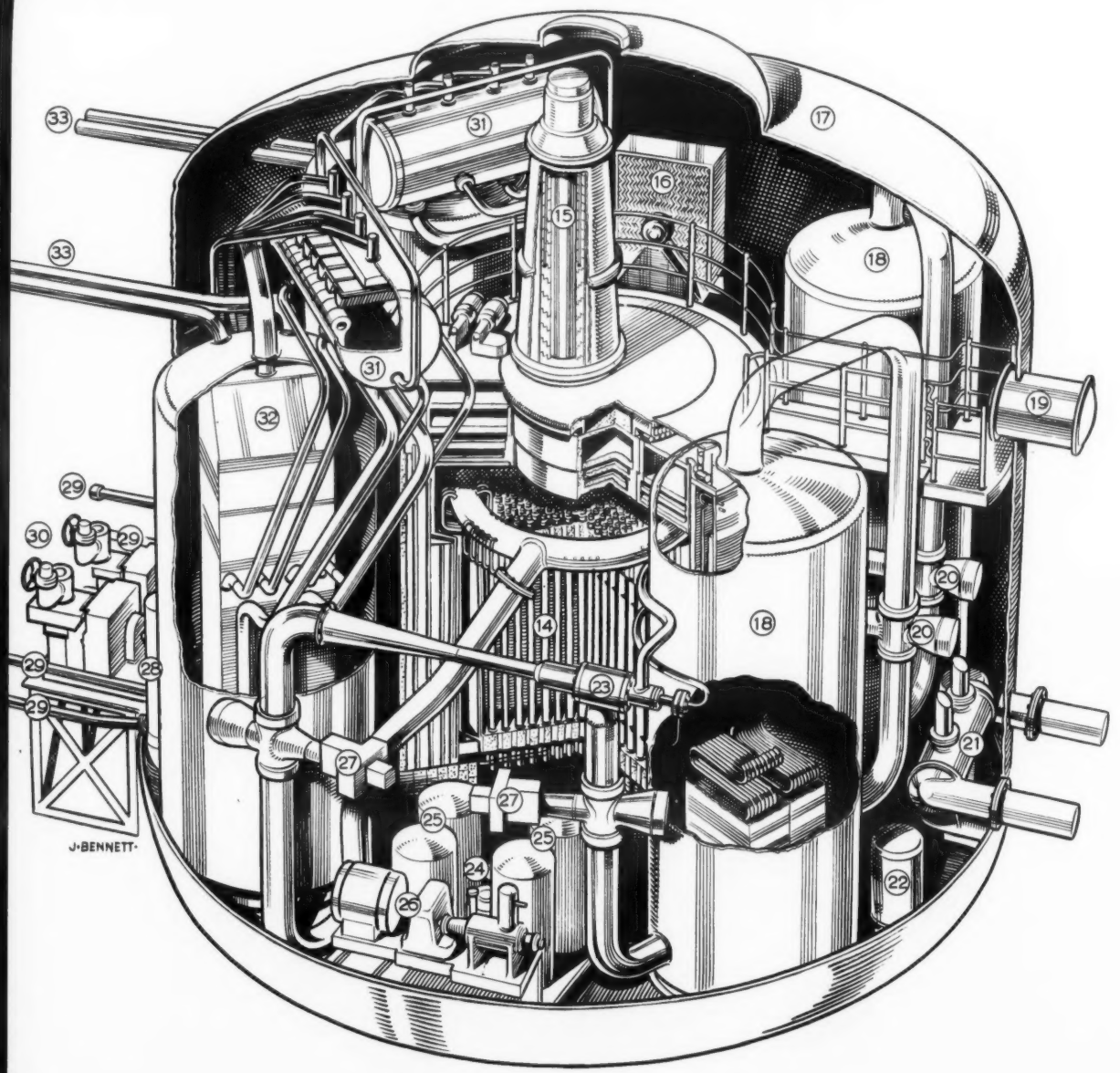
	f	p	η	ϵ	κ_∞	κ_{eff}
moderator tubes full	0·8576	0·8723	1·5963	1·0225	1·2212	1·1345
moderator tubes empty	0·8602	0·7921	1·5963	1·0225	1·1122	0·9214

initial conversion factor (average at start of life)	0·53
average conversion factor (over one core lifetime)	0·52
axial form factor	1·48
radial form factor (start of life)	1·17
average thermal flux in fuel	$2·12 \times 10^{13}$
average thermal flux over all core materials	$4·19 \times 10^{13}$

Reactor history

No reactor of this type has yet been built, though the AEA is showing increasing interest. Vickers Nuclear Engineering, comprising Rolls-Royce, Foster Wheeler and Vickers Ltd, have been working on the system for two years and are prepared to complete development from their own resources with the exception of fuel element testing and critical assembly work. The group's existing association with Westinghouse should be useful here.

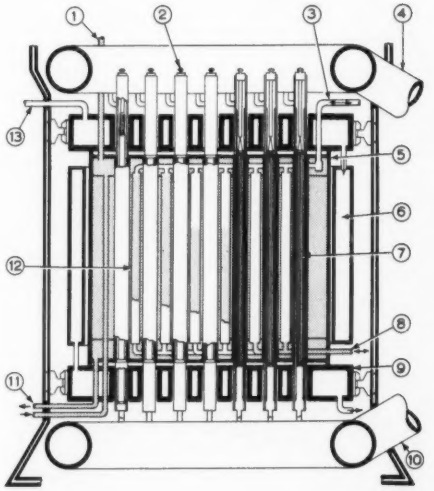
KEY
1 To header tank
2 Fuel charge tubes
3 Helium on D_2O free surface in control tubes



KEY

1 To header tank
2 Fuel charge tubes
3 Helium on D_2O free surface in control tubes
4 Steam inlet 500°F (260°C)
5 Aluminium Calandria
6 Reflector H_2O
7 Fuel element assembly
8 Control D_2O
9 Aluminium diagrid
10 Steam outlet 970°F (520°C)
11 Moderator cooling circuit D_2O
12 Control tubes
13 Reflector cooling circuit H_2O
14 Reactor
15 Charger
16 Containment cooler
17 Containment
18 Primary steam generators
19 Air lock
20 16in. isolating valves
21 Dump condenser
22 Ion exhaust vessel
23 Thermo compressor
24 D_2O pumps
25 D_2O coolers
26 Electric pump
27 18in. isolating valve
28 Economizer
29 Feed pipes
30 Drive to pumps
31 Steam drums
32 Secondary steam generator
33 9in. dia. pipes to turbine

SECTION THROUGH CORE



D_2O MODERATED STEAM COOLED SHIP REACTOR

by Vickers Nuclear Engineering Ltd.
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Expert opinion is that containment technology is still not good enough to build power reactors near towns, writes our special correspondent from Rome

Siting and safety of nuclear plant

— a report on the CNRN conference

The broad pattern which gradually evolved in the papers on siting and safety can be summarized under three headings :

1. The problems associated with the provision of reactor containment
2. The problems of identification and effect of fission product release from containment
3. The choice of suitable sites on a practical basis to fit in with the conditions peculiar to individual countries.

The opening paper, by Clifford Beck of the USAEC (1), clearly anticipated this pattern of interest. He suggested that present reactor studies on the high-rated reactors should pay particular attention to the events following loss of coolant flow or loss of coolant ; in most situations this results in partial or total core melt-out. The protection must be provided by a containment in these types of reactors and the containment problem is then specified as being adequate to contain the total energy from the pressure coolant system and from any chemical processes that subsequently develop.

Dr. Beck discussed three possible routes, currently being studied in the USA , which may ease the containment problem in the future. The first follows a detailed examination of the possibility of pressure reduction by condensation of steam. The second considers the release of the first pressure peak by venting from the containment space, assuming that during this first interval of time there has been little fission product contamination. The first release of pressure would then be terminated at an appropriate time by shutting isolating valves provided on the vent lines. The third scheme is one of a chemical clean-up of the gases and vapours in the containment space, or at the point of blow-off, by absorption or scrubbing systems. Dr. Beck did not follow these lines in detail nor suggest the degree of confidence that might be placed in them : they are at present proposals under consideration and we must wait for some time before we see the application of these to reactor systems.

A paper by M.F.R. Belot of the Belgian Bureau d'Etudes Nucleaires (2) reported problems and studies of the containment for BR2 and BR3. It was particularly interesting to hear of the detailed steps taken for testing the containment leakage, including some details of the measurement of pressure and temperature in the containment : for the latter, a long copper strip was used. The leakage rate from these containments was approximately 0·1% per day, although this might be even lower but would be difficult to assess with any accuracy. Belot also reported on extensive strain gauge tests carried out during the pressure testing of these containment vessels : from 100 to 150 gauges were applied to selected points. The information obtained from these tests indicated that the design had been on the cautious side and that there could be relaxation either in thickness, if that were so chosen, or in the standards of construction, such as the specification of shape and accuracy on the overall dimensions. For the identification of leaks in such containments, Belot still recommended the soap bubble test as being the most effective.

Underground containment looks promising

For some years there has been interest in underground containment, particularly in countries such as Sweden and Switzerland. Dr. Leardini of Società Adriatica di Elettricità (3) reported leakage tests on an underground cavern which had been prepared as a war-time air-raid shelter by blasting in an area of Dolomite rock. The cavern was sealed off with double air-lock doors which were shown to be substantially pressure-tight. The first pressure tests carried out on the cavern itself showed extensive leakage. Successive steps were then taken to seal up the cavern by pressure grouting and other surface treatments. After successive and reasonably extensive treatments, a degree of tightness was achieved which gave an exponential half-life on leakage rate of 20 days. It was considered that this might be adequate for certain types of installations ; on others, an internal sheeting would be necessary. On cost factors a paper from Switzerland (4) suggested that for certain types of plant the cost of underground containment need not add appreciably to the overall cost

of installation. This paper also considered the absorption of fission products on clays and showed that strontium and iodine in solution can be absorbed successfully in laboratory tests on certain types of clay. However, no work was published on the absorption of fission products released in vapour or gaseous state, and it would not be possible to deduce from the paper as presented whether fission products in gaseous or vapour phase would be absorbed appreciably by penetration through rock fissures.

Radiation dose limits need standardizing

Various implications of fission product release were considered in several papers (5, 6, 7, 8). In general, they came to the conclusion that adequately contained reactors need not lead to a hazard to the public at some distance from the site. Various weighting factors were placed on the importance of release of strontium, caesium and iodine, and it was particularly noticeable that the standards for acceptability of dose from iodine varied considerably in these papers. In those by Storrer and Bruchner it seemed that a limiting dose of 1000 - 1500 rad to thyroid had been taken, whereas Dopchie's paper was based on 200 rad and Fletcher and Farmer used a figure of 25 rad in accordance with recently published recommendations of the British Medical Research Council. It would be very helpful for the wide technical interests in reactor safety and siting if authoritative international figures were given for these emergency limits.

The conference

The sixth International Congress on Electronics and Nuclear Physics was held in Rome from June 16-20. Organized by the Italian CNRN, delegates from the USA, France, Israel, Germany, Switzerland, Belgium, the UK, and Sweden presented a total of 75 papers. Three days of the five were devoted to siting and safety of nuclear power plants which we cover here ; the remaining time was spent on applications of nuclear energy in chemistry and biological research, the chemistry of radiation, and economic factors.

The two papers dealing with siting in a definitive manner were those by Beck (1) and Farmer and Fletcher (8). The former summarized the proposals which were tabled in the Federal Register of the US on May 23. This relates to considerations now being given by the AEC to a regulatory amendment establishing safety criteria for reactor sites. The proposal runs : 'For any power or test reactor, a minimum exclusion radius of the order of one-half to three-quarter mile may be required.' The distances refer to an exclusion area under the complete control of the licensee. It was also suggested that power and test reactors should be located so that population density in surrounding areas outside the exclusion zone is small. It is usually desirable that the reactor should be several miles distant from the nearest town or city and for large reactors a distance of 10 - 20 miles from large cities. The British paper quoted criteria which, inter alia, have been used for the siting of reactors in the United Kingdom, namely that few people should be found within 500 yards of the site, not more than 500 people living within 1½ miles in any 10° sector round the site, and no centre of population with more than 10,000 inhabitants should be within 5 miles. The paper analysed the results following a limited escape of iodine and, using the MRC recommended emergency limits, came to the conclusion that these criteria are still largely satisfactory under the new circumstances but suggested modification in the second criterion, extending the sector to 30° and reducing the radius to one mile.

Other papers presented dealt with specific safety characteristics of reactors, such as two from America by Forbes (9) and Owen (10) on the safety of heterogeneous and boiling water plants. Paper (11) discussed the pattern of emergency organization that is recommended to deal with an accident on a reactor site, based on lessons learned from the Windscale incident.

International flavour to siting problems

In conclusion, it was felt that there is still room for considerable development in containment as reactors are inevitably moved nearer to centres of population, particularly if associated with marine projects. The problems lie not only in containment structure but in identification of the pressure conditions for which the containment should be designed and in the testing of the newly constructed container and in service during successive periods of years. The high standards of containment integrity now required - in the range of leak rate of 0·1% per day or less - demand particularly high standards in joints, glands, etc. It was also seen that the problems in siting reactors, whilst being essentially national, still have a pronounced international flavour in the development of a pattern of general acceptability.

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Semiconductors as radiation detectors

by G. I. CRAWFORD, B.Sc., Ph.D.
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Experimental work on this new technique is well advanced and Plessey Nucleonics will build a prototype instrument in the next few months

The essential difference between a conductor and an insulator lies in the relative strengths of the forces acting on the outermost, or valence, electrons of the constituent atoms of the material. In a conductor the valence electrons are very loosely bound and only a small amount of energy is required to free an electron from its parent atom ; in fact the thermal agitation of the atoms is sufficient and, at normal temperatures, there are always free electrons in the material. These electrons move in response to any applied electric field and the resulting movement of charge provides the current which may be observed by external measurement. In an insulator, however, a much larger amount of energy is required to release the valence electrons and none are normally free. Thus no charge carriers exist in the material and no current flows if an electric field is applied. If the field is increased sufficiently, of course, a value is reached at which electrons are freed by the action of the electrical forces, and the insulator breaks down.

Nature of semiconductors

A semiconductor is, simply, a material in which the binding forces are intermediate between those associated with conductors and insulators. Thus in a semiconducting material there are a small, but significant, number of conducting electrons whose number increases with the temperature of the medium i.e. a semiconductor has a negative temperature coefficient of resistance, since its ability to pass current in response to an applied electric potential increases with temperature. A conductor, on the other hand, has a positive temperature coefficient as a result of the increasing probability of collisions between the conducting electrons and the constituent atoms due to the increased thermal vibration of the atoms. This latter effect applies also to semiconductors but is less important than the increase in number of conducting electrons. The nature of the temperature coefficient of resistance is, perhaps, a more satisfactory distinction between semiconductors and conductors than the value of the resistivity.

The above discussion applies only to ideally pure materials and takes no account of the influence of the impurities which inevitably are present in real materials. The effect of impurities is particularly important for semiconductors and, in fact, the control of the number and distribution of the impurities is a vital part of the technique of their manufacture. A germanium atom for example, has four valence electrons and in pure germanium all are occupied in valence bonds with neighbouring atoms. If a small quantity of an element with five valence electrons, e.g. arsenic, is added to pure germanium, only four of its valence electrons can form bonds with the germanium atoms and the fifth remains very loosely bound and is, in consequence, easily released to become a conduction electron. Such an impurity, which easily donates conduction electrons, is known as a 'donor impurity'. Since the charge carriers responsible for the resulting increase in conductivity are negative particles, the resulting material is known as an 'n-type' semiconductor.

If, on the other hand, the impurity has but three valence electrons, e.g. gallium, there is an insufficiency of electrons in the material and the vacancy at the impurity can be filled by the capture of any free electron ; such an impurity is known as an 'acceptor' impurity. The application of an electric field to a semiconductor containing such impurities may cause the motion of valence electrons to fill the vacancies at

the impurities, so leaving other vacancies which may similarly be filled. Thus a current flows which may be regarded as a motion, against the field, of the vacancies, which are normally referred to as 'holes'. The analysis of the effect is, in fact, simplified if the current is imagined to be carried by the 'holes', which are regarded as being positively charged particles, rather than by the electrons. Materials in which conduction is so effected are known as 'p-type' semiconductors. Charge is normally carried by electrons in n-type material, by holes in p-type. If electrons or holes are introduced into the other type of material they are referred to as 'minority carriers'.

All radiation detectors rely on the ionizing properties of charged particles. When a charged particle passes through matter it undergoes many collisions, mainly with the orbital electrons of the constituent atoms, transferring a small proportion of its energy to each. (This energy, nevertheless, is usually sufficient to release the electron from the atom). Detection is then accomplished by collecting the charge carried by the ions with the aid of an applied electric field, (as in an ionization chamber, proportional or geiger counter) by observation of the light emitted as electrons move between bound states to fill the vacancies (a scintillation counter), of the condensation of vapour on the ions (a cloud chamber), or of the blackening produced by them in a photographic emulsion. The passage of charged particles through an insulator or semiconductor may therefore be expected to cause an increase in the number of free electrons and hence to increase the conductivity of the material. In fact electron-hole pairs are created, and the subsequent motion of each determines the possibility of using the material as a practical radiation detector.

Similar behaviour of insulators

Though not strictly included by the title of this article, the possibility of radiation detection by observation of conductivity changes in insulators is so closely related to the similar use of semiconductors as to justify its discussion here. From the properties mentioned in the previous two sections, one might deduce that an insulator should be an effective radiation detector. If an electric potential is placed across an insulator, no current will normally flow. The passage of a charged particle, however, will, by forming electron-hole pairs, reduce the resistivity of the medium and current will flow. The electrons and holes move in opposite directions in response to the electric field with velocities which are the product of the field strength and a constant, known as the mobility of the particle, which is greater for electrons than holes.

In practice such currents are observed to flow when, for example, diamonds are exposed to a source of alpha-particles. However, the response of such a detector is less ideal than might have been expected. In particular, there are wide variations in the outputs of different crystals and even between different regions of a given crystal. These are caused either by impurities in the chemical composition of the material or by flaws in its crystal structure. The imperfections can attract the charge carriers in the materials and then trap them, thus reducing the flow of current. Moreover, the presence of these trapped charges sets up local electric fields which further restricts the passage of the carriers. The lower the applied field, the lower the drift velocity of the carriers and hence the longer they spend in the vicinity of each imperfection and the greater is the chance of capture.

This 'space charge' effect can be reduced by heating the detector, by exposing it to light, by increasing the applied field or by applying an a.c. field. However, despite these attempted remedies, the output is still far from constant and it must be assumed that even in very good insulators there exist regions in which the conductivity is unusually high. In such a region the electric field gradient would be lower than normal, and the effect of irradiation upon such a region would be much less than in a region of relatively high field.

The overall effect of these inhomogeneities is to reduce greatly the value of such materials as detectors. For although individual crystals may have good properties, there seems little prospect of producing large numbers with sufficient uniformity of response to permit their use on a large scale. However, the nature of these deficiencies suggests a second class of material which also show prospect of providing suitable properties for radiation detection.

THE RESULTS

Experiments in the UK, USA and USSR show that semiconductors can be applied to measure all types of radiation

Charged particles: high intrinsic efficiency with n-p junctions

Fast and slow neutrons: efficient indirect methods with an n-type coating on an n-p junction

Gamma radiation: some success with single crystals or layers

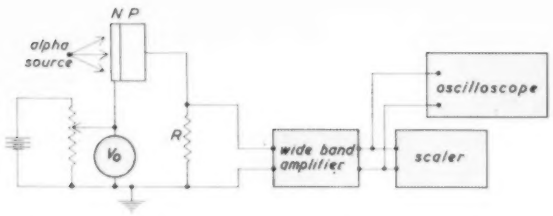
THE ADVANTAGES

Direct reading system with small physical size

How radiation is detected

As indicated in an earlier section, the conductivity of semiconducting materials is strongly dependent on the concentration and distribution of impurities, either donor or acceptor. The great advances made in recent years in the manufacture of transistors stem mainly from improvements in control over the addition of such impurities to exceedingly pure semiconducting materials. Thus one might well hope that the number of undesirable imperfections can be sufficiently controlled to produce crystals with a more uniform response to radiation than the natural insulators.

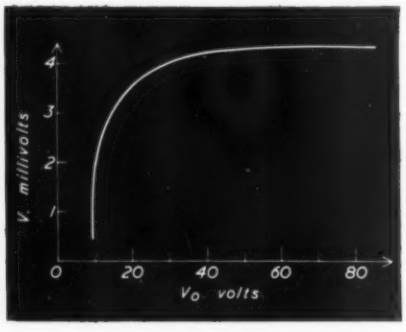
It has, in fact, been demonstrated that semiconducting crystals may operate as radiation detectors. However, a wide range of output pulse sizes is still obtained when such crystals are exposed to mono-energetic alpha-particles. It is conventional to refer to the smaller pulses as the 'primary current' and the larger as 'secondary'. The mechanism of primary current formation is believed to be the simple increase in conductivity, due to the release of free charge carriers by the radiation which has been discussed above. A plausible explanation of the secondary current may be based on the nature of the electrical contact made to



Counting characteristics of a p-n junction in germanium were examined with this circuit in the USSR by Airapetiants and Ryvkin (Fig. 1)

the crystal. If a soldered connexion is made, or if the contact is made by electrodeposition on to a ground surface, an ohmic contact is formed and no secondary current is observed. However, electrodeposition on to an etched surface results in a rectifying contact and irradiation in the neighbourhood of such a contact, which is biased negatively, results in the formation of large secondary pulses.

It has been suggested (1) that the holes, which are attracted towards the negative electrode, may be trapped at the metal-semiconductor interface, and that the positive field due to the holes attracts electrons from the metal and, by lowering the potential barrier which normally inhibits their flow, permits them to pass into the crystal. The currents are large because each hole may permit the passage of very many electrons, and the duration of the current is relatively long since it is



Results from the circuit above showed this relation between pulse height and basic voltage (Fig. 2)

equal to the lifetime of holes at the barrier before recombination takes place. The pulse length for the primary current is dependent on the time taken for the electron and holes to traverse the crystal. The electron mobility is greater than that for the holes, and hence, the shortest pulses occur when irradiation takes place near the negative electrode.

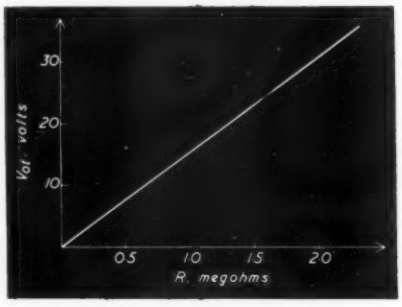
The secondary pulses produced in this way vary widely in size from crystal to crystal due, no doubt, to slight variations in the metal-semiconductor interface. However, another type of rectifying junction exists which may more easily be consistently manufactured, i.e. the junction between an n-type and a p-type semiconductor. If the negative electrode is in the n-type region and the positive in the p-type, the crystal is so biased that little current will normally flow.

It has been demonstrated (2) that a p-n junction in germanium may act as an efficient alpha-particle detector. In the experiments of reference (2) a rod of germanium was used which was 2 cm long by 1 mm square, with a p-n junction of width 5×10^{-4} cm in the centre, normal to the length of the rod. The radiation from an alpha-particle source was collimated by a rectangular slit placed parallel to, and above, the junction to a width of $3 \cdot 5 \times 10^{-3}$ cm at the crystal. With ohmic contacts at the ends of the rod and negative bias applied to the p-type region, uniform pulses were obtained for bias voltages in the range 0·3 to 15 volts ; the pulse height increased with increasing bias voltage but reached a saturation value at about 10 volts. The efficiency for detecting the incident alpha-particles was 100%.

The disadvantage of this system lies in the necessity to collimate the radiation since the overall detection efficiency must therefore be very low, despite the 100% intrinsic detection efficiency for particles striking the junction. All particles of a given energy which strike the crystal at a distance from the junction which is less than the diffusion length of the minority carriers in that region produce equal current pulses. However, if the particles are incident at greater distances, a smaller number of current carriers reach the junction and a non uniform series of output pulses are obtained.

Determination of detector characteristics

This difficulty is overcome if the n-type region is made very thin - less than the diffusion length for holes - and if the radiation is incident normal to the plane of the crystal on that region. In this case the upper limit on the sensitivity of the detector is given by the maximum area of crystal which can be grown. The characteristics of such a detector have been carefully determined (3). Figure 1 shows the experimental arrangement. A variable positive voltage V_o was applied to the n-type region, which was exposed to the alpha-particles from a Po-210 source. The pulses developed across the resistor R were fed to a wideband amplifier whose output pulses were displayed on an oscilloscope, in addition to being counted by a scaler. Figure 2 shows the variation of pulse height V with bias voltage V_o for a fixed value of the resistor R. It is found that an increase in R leads to an increase in the output pulse height, but at the expense



Variation of threshold bias with load resistors (Fig. 3)

of an increase in threshold voltage V_{ot} at which counting starts. Figure 3 illustrates the variation of V_{ot} with R.

The variation of signal-to-noise ratio with temperature has also been studied. It is found that the signal varies only slightly with temperature but that the dark current is very temperature dependent. Thus the signal

to noise ratio, already good at room temperatures, is excellent at lower temperatures. Table I lists some of the results found.

Table I

Temperature of junction	Pulse size V	Signal to noise ratio
300° K.	3 → 5 mV	6 → 15
4·2° K.	2·2 → 3·2 mV	50 → 60
1·5° K	2·9 → 3·5 mV	80 → 100

Gamma detection with cadmium sulphide

The results so far discussed have concerned particle bombardment of semiconductors. Much work has also been done on the sensitivity of certain semiconducting materials to gamma-radiation. Cadmium sulphide has most frequently been employed and will be used as an illustration in this section. Generally single crystals have been used, but it has also been shown (4) that, under certain carefully controlled conditions, polycrystalline layers can be grown which have a larger surface area than normal single crystals and, in consequence, a higher sensitivity. With such a detector, of diameter 2 cm, operated with a bias voltage of 10V, currents as in Table 2 have been obtained, with a dark current (in the absence of radiation) of about 0·1 μa.

Table II

Radiation dose-rate	Approximate current
1·8 r/h	15 μa
8 r/h	80 μa
50 r/h	550 μa
2000 r/h	10,200 μa

Thus a very simple detection system, in which a d.c. microammeter is used as the measuring device, may be employed.

The disadvantage of such detectors lies in the relatively long time - up to tens of minutes - for the current to build up to its saturation value. (The currents shown in Table 2 are measured at saturation). The time depends on the dose-rate, the crystal, and the previous history of the latter. Significant reductions can be achieved by exposing the detector to gamma radiation or light before making a measurement ; a convenient method is to store the detector close to a radioactive source.

Indirect techniques for neutrons

Direct detection of neutrons has not as yet proved practical, but efficient indirect techniques exist, based on the use of a p-n junction as a charged particle detector (5). The charged particles are produced by the scattering of protons by fast neutrons, by fission - U-235 or U-238, for example, or by such reactions as B-10 (n,α) L-7. A thin coating of the target material is applied to the n-type region of an n-p junction in either germanium or silicon, similar to those described in an earlier section, and the charged particles emitted when neutrons interact with this coating are detected as before. (For fast neutron detection by scattering of protons the optimum thickness of hydrogenous material is 1 mm). With counters of this general form, and of diameter of the order of 1 mm, sensitivities to thermal neutrons may typically be of the order of 10^{-3} to 10^{-7} counts per neutron per square centimetre. The higher efficiencies apply to thermal neutrons ; the lower to fast neutrons. These efficiencies compare favourably with those of the smallest conventional counters at present available. Such detectors have a negligibly low response to gamma radiation.

It has been demonstrated (6) that the pulse heights obtained when a semiconductor detector is bombarded by charged particles are proportional to the particle energy ; the pulse height is not dependent upon the nature of the particle (7). An energy resolution of 3% for 5 MeV alphaparticles is possible, which compares very favourably with other particle detection techniques.

The pulse length obtained from such detectors is generally long - of the order of microseconds. However the rise time may be very short (7) - below 3×10^{-9} seconds - which permits the very accurate timing which is necessary for fast coincidence work and time of flight spectrometry.

Small size the great advantage

The most promising type of semiconductor for use as a radiation detector is an n-p junction in germanium or silicon, which may be preferable at higher temperature. Such a detector has a high intrinsic efficiency for the detection of charged particles and, with suitable coatings, may be used as a detector for fast or slow neutrons. For the detection of gamma radiation cadmium sulphide crystals, or polycrystalline layers, are to be preferred.

The principal advantage of these detectors lies in their small physical size which permits a spatial resolution at least as good as that obtainable with foil techniques, with the great advantage over foil techniques of providing a direct reading system.

Further development is required before the wide-scale use of semiconductors as radiation detectors will be possible and, at present, the possible extent of their usefulness is not clear.

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Shell-Mex has produced a whole new range of oils and greases for nuclear use in Bradwell and future power station designs

Developing radiation-resistant lubricants

by H. C. O'CONNER, B.Sc., PH.D., A.M.I.MECH.E
Lubricants Dept., Shell-Mex and B.P. Ltd.

When nuclear engineering became a reality, it was obvious that in some applications there would be fundamental new problems of lubrication. In their resolution difficulties likely to arise in all civil uses of nuclear power had to be borne in mind, not only those forseeable in static nuclear power units.

In the first generation of nuclear power stations we are concerned with low relative speeds and low surface loadings, but with the complication of high temperature, controlled atmosphere, and a radioactive environment. Problems involving lubrication at elevated temperatures have been met in numerous applications in the past ; those involving an atmosphere other than that of air are less common, but some knowledge has been gained in the past ; those of lubricating in a radioactive environment were entirely new when work began at Thornton Research Centre in 1953.

High flux tests in Bepo

First the effect of radiation on hydrocarbon mineral oils was determined. In preliminary experiments (1) three oils of differing compositions were exposed to radiation in Bepo at a point where the flux was about 10^{12} n/sq.cm. Oil temperatures during irradiation were between 60°C and 70°C. It was found that hydrocarbon oils crosslink and increase in viscosity to varying extents according to the composition of the oil (Fig.1). Oil A, a paraffinic solvent extracted Brightstock of relatively high molecular weight, was solid after a total dosage of $1 \cdot 8 \times 10^{18}$ n/sq.cm. Oil B, a paraffinic solvent extracted distillate of lower viscosity than A, suffered an increase of kinematic viscosity of 2620% after having received a dosage of $1 \cdot 77 \times 10^{18}$ n/sq.cm. Oil C, a solvent extract of a naphthenic distillate containing about 92 w/o of aromatic compounds, suffered a 340% increase in kinematic viscosity at $1 \cdot 77 \times 10^{19}$ n/sq.cm total dosage.

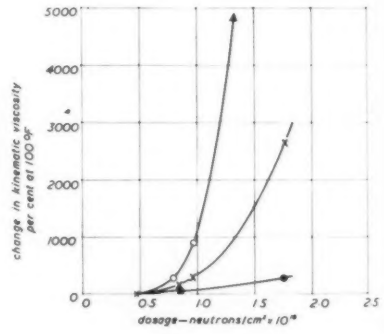
The stability of aromatic materials in general under nuclear radiation has in fact been demonstrated before (2), and it has been shown that there is a significant decrease in the viscosity change during irradiation with increasing aromatic compounds. It has also been shown that oils of high viscosity and molecular weight are less stable to the effects of nuclear radiation than lower viscosity materials.

In addition to the investigations using Bepo, separate experiments involving bombardment of oils with fast electrons and gamma irradiation from a cobalt-60 source were conducted in order to obtain some correlation between effects of different types of radiation on mineral oils. As a result it was found that increase in viscosity provided a convenient and effective measure of radiation damage.

The isolation of oils with high stability to radiation was only the preliminary step : any lubricants used in irradiated environments must still function adequately as lubricants and must not deteriorate in use through any other cause. In addition, the use of oil, particularly in such members as anti-friction bearings, involves the provision of elaborate sealing to prevent its escape into areas where contamination would be undesirable. It was therefore necessary to produce suitable greases and to test both oils and greases to ensure that they possessed adequate lubrication properties.

Oil A ○ Oil B × Oil C ●

After irradiation in Bepo, three hydrocarbon oils showed wide differences in stability (Fig. 1)



Greases based on metallic soaps could be described as oil bound in a matrix of soap crystals. Quite the most superior grease now in common use is that in which the soap is lithium hydroxy-stearate. Irradiation experiments on sodium and lithium-based greases indicated a significant breakdown in the soap structure. This was evidenced first by a softening of the grease and then, as the total dosage increased, a hardening. It was found necessary to employ inorganic gelling agents in order to overcome these difficulties. The

greases thus produced were known to be capable of withstanding high radiation dosage without deterioration. It remained to demonstrate their ability to lubricate adequately at elevated temperatures and in an atmosphere of carbon dioxide at about 10 atmospheres pressure.

Suitable testing rigs in which carbon dioxide pressure and temperature could be controlled were built and the abilities of the greases proved (see Figure 2). As a final demonstration a rig was constructed which enabled a grease-packed roller bearing running in a carbon dioxide atmosphere at 150°C and 150 lb/sq.in. to be lowered into Bepo.

Range of oils and greases developed

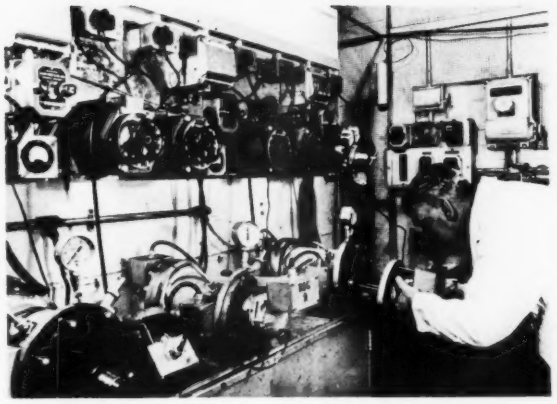
The general development has resulted in a range of lubricating oils of different viscosity suitable for use at radiation dosages up to $1 \cdot 6 \times 10^{18}$ n/sq.cm. It has proved possible to incorporate additives with some oils in order to confer special properties. A good example is the inclusion of anti-rust, anti-foam and anti-oxidant compounds in an oil for use in hydraulic systems. Radiation dosages up to $1 \cdot 0 \times 10^{18}$ n/sq.cm can be safely applied in this case.

Of radiation resistant greases developed, the most advanced in properties of radiation resistance shows no change in physical properties after exposure to a radiation dosage of $1 \cdot 8 \times 10^{18}$ n/sq.cm and has operated successfully for over 5500 hours in a 20 mm ball bearing test rig running at 1500 rev/min in a carbon dioxide atmosphere at 150°C and pressure of 150 lb/sq.in.

Applications in Bradwell machinery

In the control rod actuators, parts to be lubricated include anti-friction bearings and seals. As neutrons are effectively shielded, the radiation in the control rod mechanism will be principally gammas derived from the steel chain by which the control rod is suspended. This chain is exposed to pile radiation when the control rod is fully lowered and on retraction is wound on to a drum within the mechanism, thus providing a source of gamma radiation. The mechanism contains carbon dioxide at 150 lb/sq.in. and the temperature is not expected to exceed 100° C. The speeds during normal operation are very low but during emergency shutdown bearings can reach a peak of 3000 rev/min for short periods. Because the mechanisms are in the coolest position in the reactor it is possible that condensation will occur and protection against possible corrosion is necessary. An operational life for the lubricant of the order of four years is envisaged. This application does not call for an extremely high radiation resistance from the lubricant and Shell APL 701 is used to pack the bearings and seals.

The position of maximum radiation in the charge machine is adjacent to the magazine. Here most of the radiation is in the form of gamma rays from used fuel elements. The maximum dosage in the region of the valve near the base of the machine is estimated at about $1 \cdot 3 \times 10^{7}$ rads per year. Maintenance operations



In these rigs 20mm bore ball bearings are tested at 1500 rev/min in carbon dioxide at 150 C and 150 lb/sq.in. (Fig. 2)

can be carried out at intervals of three months and the lubricants used will be required to withstand about 3×10^{6} rads without deterioration.

In most positions it has not been necessary to apply lubricants with extremely high resistance to damage by radiation. However, where grease-lubricated bearings are in a position which is irradiated, Shell APL 701 is used for packing. These positions occur in the element hoist drive, where the grease is also used in a small bevel gearbox, in the sealed bearings of the weighing mechanism, in the service hoist and turret, and in vertical shaft bearings of the chute headboxes and radius gear. Thereafter, in the transfer carriage, basket crane and coffin crane it has not proved necessary to use a special radiation resistant grade.

In each gas circulator a carbon dioxide mass-flow of 903 lb/s during normal operation is expected. Normal speed will be 3000 rev/min, static inlet pressure 139·9 lb/sq.in. absolute and outlet pressure 147·5 lb/sq.in. absolute. The static outlet temperature will be 180° C. Two independent driving means are fitted - a motor capable of driving the circulator at 20% speed, and the main drive capable of driving from 20% to 110% normal speed. Squirrel cage induction motors supplied from auxiliary turbogenerators are used.

Radiation in the system will be low. The lubricant is required for shaft bearings, driving motors, and as gas seals. Thus the oil used must be of similar standard to turbine oil from the point of view of oxidation stability and corrosion resistance, and in addition must have a very low gas solubility and vapour pressure. The oil to be used at Bradwell - Shell APL 729 - was originally developed for Calder Hall.

For anti-friction bearings, gland packings and other grease-lubricated components in the butterfly valves of the main gas circulating system, the requirement again is for a grease unaffected by high temperature and pressure of carbon dioxide, and radiation resistant : again Shell APL 701 was used.

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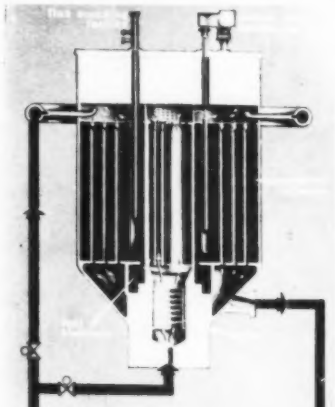
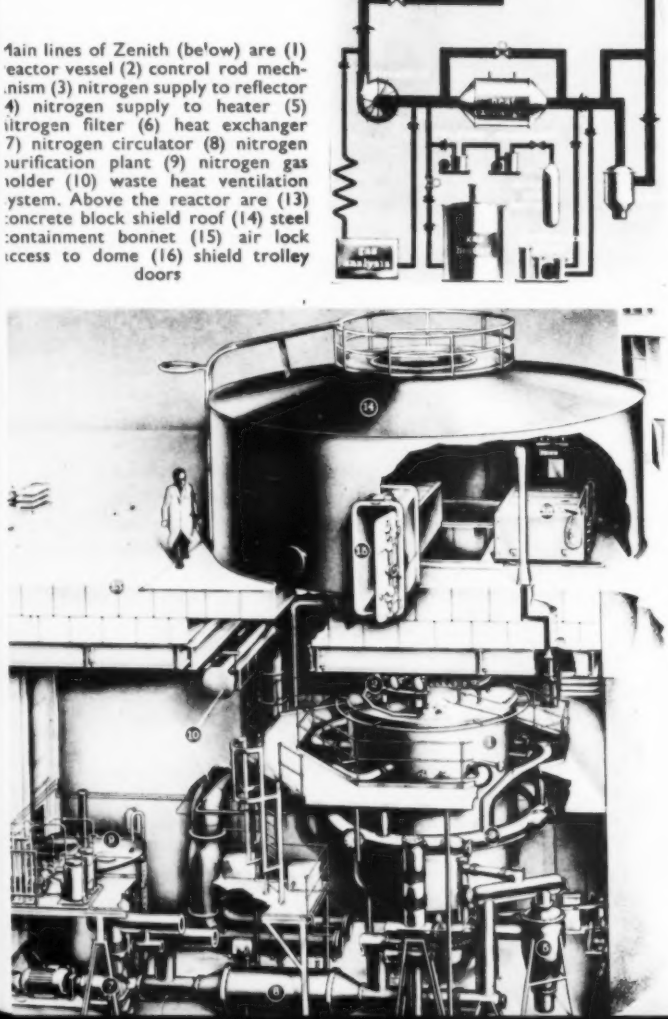
ust beyond the roundabout in the oreground is the zero energy section with the single storey administration olock and Reactor Hall No 2 complete. Beyond these is the Central Technical Building. Beside the railway is the Apprentice Training School (extreme right) the General Services Building and the T-shaped Reactor Group offices



Right. A system of valves and by-passes is used in Zenith to control core and reflector temperature

Main lines of Zenith (below) are (1) reactor vessel (2) control rod mechanism (3) nitrogen supply to reflector (4) nitrogen supply to heater (5) nitrogen filter (6) heat exchanger (7) nitrogen circulator (8) nitrogen purification plant (9) nitrogen gas holder (10) waste heat ventilation system. Above the reactor are (13) concrete block shield roof (14) steel containment bonnet (15) air lock access to dome (16) shield trolley doors



From now on work on industrial nuclear power generation up to the small prototype stage will shift from Harwell to

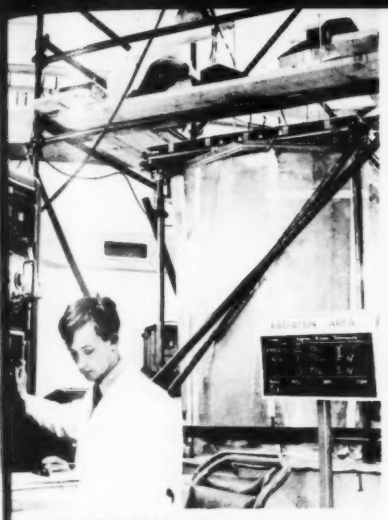
AEE
Winfrith Heath

When the first of the European teams for the Dragon project (April p102) arrives at the Atomic Energy Establishment, Winfrith, in September they will join many other newcomers to the 700 acre site. The High Temperature Reactor Division from AERE Harwell will be already established and over the next few months nearly all the physicists, mathematicians and engineers at Harwell who are directly involved with basic work on the industrial generation of atomic power will move there. In eighteen months the AEA has created a new establishment from a tract of marshy heath and NUCLEAR POWER recently went to see the results of their work.

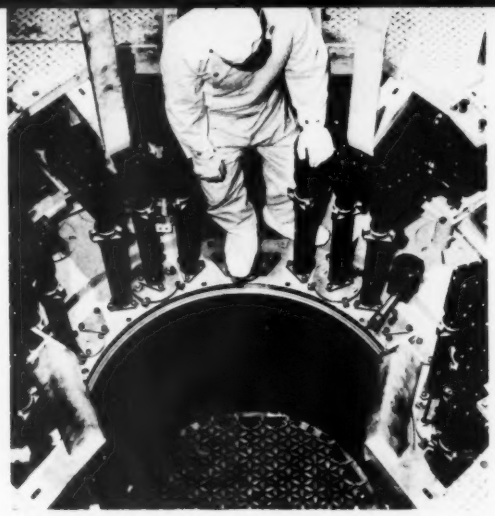
£M5 spent so far

About 200 acres of the total 700 are being developed initially by the main contractors, the Turriff Construction Corporation. Six possible reactor sites are arranged round a central complex of buildings, the main ones of which are two zero energy halls (one finished), the reactor group offices, almost completed and partly occupied, the general services building, containing a 72,000 sq. ft workshop (completed), the central technical building and the Apprentices School (operating). Other major buildings still to be erected are a health physics building, a medical centre, space for the control and instrumentation work, a building to house a Mercury digital computer, and offices for the Dragon project. 'We have spent about £M5 so far' said D.W. Fry, director of the Establishment. 'The order of capital investment when the site is fully developed might be of the order of £M20-30 and we expect to have 2000-2500 people working here'. Collaboration with the AEA's northern groups will be close, and ties with industry will be signalled by the arrival of BICEP British Industrial Cooperative Exponential Programme in a few month's time.

The main aims of Winfrith were summarized by Mr. Fry under three heads : (1) to lower capital costs and improve the efficiency of the gas-cooled graphite-moderated reactor, (2) to develop ways of using plutonium as a fuel, and (3) to study reactor systems to operate on a low load factor, including propulsion systems. This will mean a broad front of basic work on light and heavy water-moderated systems - including



THE BEGINNING. Properties of fuel elements for Zenith were investigated by assembling them in a cylindrical exponential stack and measuring flux distribution



INSIDE ZENITH. Control rods and flux measuring apparatus line the inside of the top face of the reflector. Over these can be seen the top of the reactor vessel itself

OUTLET TO THE SEA. Five miles away from AEE divers are blasting a level along the sea bed to lay these effluent pipes up to two miles out from the coast

boiling water reactors and steam-cooled systems - and organic liquid moderators, leading to selection of one which could be carried through to the reactor experiment stage. The reactor experiment or small prototype will mark the limit of the AEE's work.

Experimental installations to be built will include hot contained exponential assemblies and a reactor source (now being designed) to drive them. Besides Zenith, the zero energy high temperature reactor, a further zero energy assembly will be built, and a Race analogue computer is already being used for dynamic studies of the operational behaviour of possible reactor systems. In the immediate future the other half of the Zenith building will be used for a mock-up of the Dragon core to investigate loading and unloading etc.

The first nuclear research tool to be operated was the Zenith exponential experiment - a sub-critical cylindrical assembly of fuel elements mounted vertically on a graphite pedestal. The flux is generated by four radium beryllium neutron sources in the pedestal and falls off exponentially with height. The elements themselves are graphite sleeves packed with discs of thorium oxide and uranium oxide (93·5% U-235) of the order of 1/8in. thick and graphite pellets which can be rearranged in the sleeves to investigate the properties of different core loadings for Zenith. It takes about a month to change from one pattern to another, and five have been tested so far. Neutron flux measurements are made with boron trifluoride counters lowered into the gaps between elements, and with metal foils. The flux levels are low enough to allow the elements to be freely handled, and a metal sheet round the assembly gives sufficient shielding.

Zenith completed

Meanwhile the General Electric Company has completed Zenith, which will be rented to the Dragon project to check the reactor physics design calculations being done for the 20MW reactor experiment. Testing and commissioning has already begun but the team must tread warily in view of the research reactor's high temperature and novel design and it may not go critical before the end of the year. In the past, experiments to study power reactor designs have been carried out in zero energy reactors operating at room temperature ; although this is satisfactory for modest temperatures, the degree of extrapolation involved in assessing the behaviour of high temperature systems is unacceptable and Zenith has been built to operate under temperature conditions similar to those expected in a high temperature power reactor. The core consists of fuel elements arranged in the same manner as those used in the exponential experiment, though the elements differ in that the ends are made of solid graphite. These and a 3ft thick graphite annulus surrounding the fuel form the reflector.

Nitrogen gas is circulated through the core from an external circuit mounted in a pit beneath the reactor vessel. It is heated by a 250kW heater on entry to raise the core temperature to 800°C and at the top of the core the hot nitrogen is mixed with cooler gas before passing through the reflector. A system of valves and by-passes in conjunction with thermocouples enables temperatures to be accurately controlled in each and reflector temperature is kept below 400°C. At these temperatures it is most important to maintain the purity of the gas and separate by-pass circuits are used for continuously purifying part of the gas and for analysing it for oxygen, carbon monoxide and carbon dioxide. The reactor itself will be operated at a maximum of 100 watts - a negligible amount in comparison with the energy used to heat the core. The instruments used in studying the core are placed at the inner edge of the reflector and a ring of thirty control rod holes surround the core. The operating power is sufficient for the nuclear physics measurements and is sufficiently low to avoid inducing such high activities in the fuel that rearrangement of the core would be difficult to carry out.

The size and shape of Zenith are almost the same as those of the proposed 20MW reactor experiment. Work on control problems, temperature coefficients and critical sizes will be of immediate application while measurements of neutron spectra and effective cross-sections will improve calculations of such effects as fission product absorption which cannot be observed directly in Zenith. When this work is completed the reactor will be used for research in connection with the Authority's long term research programme on high temperature systems.

Experiments on Doppler broadening

A tendency to increased Doppler coefficient of uranium metal bars with decreasing diameter has now been observed experimentally by V.G. Small of AERE (Report R/R 2774 - 'An experimental determination of the increase with temperature of the resonance absorption in uranium and thorium'). Since Doppler broadening leads to a decrease in the resonance escape probability, p, and hence to a negative reactivity contribution to the temperature coefficient of a thermal reactor, knowledge of the Doppler coefficient of the fuel is of importance for temperature coefficient and safety considerations. This is especially so in the event of a sudden power surge, since then the temperature of the fuel rises much more rapidly than that of the moderator so that the fuel coefficient of reactivity is initially more important than the moderator temperature coefficient.

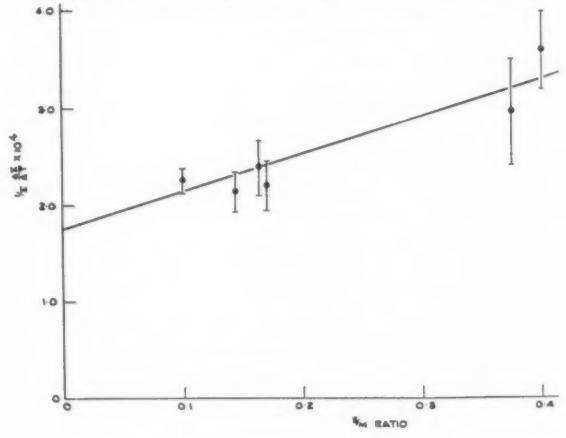
Using the Dimple pile oscillator measurements were made of the change in effective cross-section of the various samples as a function of their temperature which, after application of certain corrections, led to values of the Doppler coefficient. The bars were enclosed in an aluminium furnace and heated electrically, continuous temperature monitoring being achieved by means of an iron-constantan thermocouple. It was necessary to take steps to keep the moderator from becoming heated when hot bars were oscillated, since this would have produced a reactivity change through the moderator temperature coefficient. Radiative heat losses were reduced by polishing the inside of the furnace and evacuating it, the latter also serving to prevent oxidation of the bars at the elevated temperatures used. On account of the high resonance absorption and low value of W (0·7) at the sample position, where W represents the relative importance of a fission neutron to that of a thermal neutron, both the uranium and thorium bars acted as marked absorbers. The total effective cross-section of the bars and furnace together was of the order 10 cm^2 and too large for oscillator measurements, so it was decided to compensate this with U-235/aluminium alloy in order to reduce the effects to within the practical limits of $\pm 1 \cdot 5 cm^2$.

The furnace consisted of an aluminium tube 13 in. long and 2½ in. in diameter with welded aluminium ends. An inner aluminium tube, located centrally in the 2½ in. tube at the top and bottom by stainless steel rods, had a 40ohm nichrome heater wound on it, which was insulated with mica. Various samples up to 1 in. in diameter were placed in this inner tube and located by means of small aluminium tube spacers. Thermocouple leads passed into a small hole in the end of the test sample and they were insulated by thin silica tubes. It was found that with a pressure of about 10^{-4} mm Hg in the furnace and an electrical heat input of 50 watts the temperature on the outside walls was about 80°C when the inside temperature was about 300°C. Every effort was made to keep the absorption cross-section of the furnace as low as possible, and finally a cross-section of less than $4 cm^2$ was achie-

Bar diameter, in.	Length, in.	S/M	σ_{ri}	Σ_{ri}, cm^2	$\frac{\Delta\Sigma_{ri}}{\Delta t}$	Coefficient $\frac{1}{\Sigma_{ri}} \frac{\Delta\Sigma_{ri}}{\Delta t}$ excluding 1/v	Coefficient including 1·2b 1/v contribution to σ_{ri}
0·976	3	0·100	10·62b	1·89	$4 \cdot 24 \times 10^{-4}$	$(2 \cdot 24 \pm 0 \cdot 14) \times 10^{-4}$	$2 \cdot 0 \times 10^{-4}$
0·612	4½	0·147	12·27b	1·26	$2 \cdot 73 \times 10^{-4}$	$(2 \cdot 17 \pm 0 \cdot 22) \times 10^{-4}$	$2 \cdot 0 \times 10^{-4}$
0·543	3	0·169	12·96b	0·703	$1 \cdot 55 \times 10^{-4}$	$(2 \cdot 20 \pm 0 \cdot 22) \times 10^{-4}$	$2 \cdot 0 \times 10^{-4}$
0·543	4½	0·165	12·84b	1·041	$2 \cdot 51 \times 10^{-4}$	$(2 \cdot 41 \pm 0 \cdot 26) \times 10^{-4}$	$2 \cdot 2 \times 10^{-4}$
0·230	3	0·399	18·42b	0·170	$6 \cdot 10 \times 10^{-5}$	$(3 \cdot 59 \pm 0 \cdot 36) \times 10^{-4}$	$3 \cdot 4 \times 10^{-4}$
0·230	4½	0·376	17·95b	0·243	$7 \cdot 13 \times 10^{-5}$	$(2 \cdot 93 \pm 0 \cdot 58) \times 10^{-4}$	$2 \cdot 8 \times 10^{-4}$

Fig. 1 Doppler change in resonance absorption per °C rise in temperature for uranium bars of various S/M ratios, based on $\sigma_{ri} = 2 \cdot 81 + 24 \cdot 7 \sqrt{S/M}$ excluding 1/v

Fig. 2 Inferred Doppler coefficient against S/M ratio (uranium) excluding 1/v contribution to the thermal cross-section



ved. Moderating materials were excluded in its construction to avoid giving rise to reactivity effects which depended on the furnace temperature.

A Doppler coefficient was calculated for thorium from the expression

$$k = \frac{1}{\Sigma_r}\frac{d\Sigma_r}{dt} = \frac{1}{\Sigma_r}\frac{\sqrt{\pi}}{2r}\sqrt{\frac{T_o}{T}}\frac{d\Sigma_{eff}}{dt}$$

where Σ_r = resonance integral above $\frac{1}{v}$

T = neutron temperature

$T_o = 293^{\circ}K$

For a uranium bar a similar expression was obtained assuming that the U-235 cross-section is temperature independent and the effect is only due to U-238.

Results for uranium are shown in Fig. 1 and a graph of inferred Doppler coefficient against S/M ratio for uranium metal bars is shown in Fig. 2. This shows a tendency to increasing Doppler coefficient with increasing S/M ratio.

Nuclear Technology | Instrumentation

Effects of radiation on TV camera components

Good progress has been made in developing components for TV cameras which can withstand radiation levels inside a reactor core, but much still remains to be done. A summary of the present position was included in a paper on 'The application of closed circuit television in the nuclear industry' by P. Barratt and I.M. Waters of Pye Ltd, read to the Brit. IRE convention at Cambridge in July. Their table illustrates the wide variety of effects which can occur and the lack of uniformity in the doses at which they become significant. Rules for the designer to remember include :

(i) Components used should not contain elements with high absorption cross-sections

(ii) Where structural strength is required, metals should be used, remembering that iron, cobalt, etc. become highly active, and aluminium is, in general, most suitable

(iii) Undue confidence should not be placed in the insulating properties or mechanical strength of many plastics

(iv) The use of air-gaps for insulation should take into account the ionized state of the atmosphere in the equipment, which is the result of irradiation

(v) Materials should not be used which evolve corrosive substances under irradiation

(vi) The dimensional changes of some irradiated materials must be allowed for by increasing tolerances

(vii) The use of magnetic materials containing cobalt is undesirable because the induced activity has a long half-life. Solenoids may be used to produce magnetic fields, or electrostatic focus employed where applicable.

These are not exhaustive rules, and for a given application it is desirable to examine every component which is to be used by preparing a statement of every element it contains. It is then relatively easy to predict qualitatively any unfortunate effects. The results of such analyses are often surprising : many components contain considerably more than ten elements in significant amounts.

In some cases it is necessary to allow for a characteristic of radiation damage which complicates the 'integrated dose effect'. This is the 'rate effect' - changes defined by the magnitude of the incident flux and existing only while the radiation flux persists. On removal of the flux, the property magnitude reverts to a

EXAMPLES OF RADIATION DAMAGE IN ELECTRONIC COMPONENTS AND MATERIALS

Component or material	Radiation Dose or Flux	Radiation Damage
CAPACITORS - electrolytic (boron containing)	10^{17} n.cm^{-2} approx. 10^{16} gamma cm^{-2} + 10^{17} n.cm^{-2}	Failure due to gas evolution Capacitance decrease approx. 10% ; power factor decreases 3% to 30%
CAPACITORS - oil-filled	10^{18} n.cm^{-2} or $+5 \times 10^{15}$ gamma cm^{-2}	Oil leakage ; capacitance decreases approx. 10%
CAPACITORS - paper and mica	$+10^{17}$ n.cm^{-2} or $+10^{16}$ gamma cm^{-2}	Worst effect observed is capacitance change of a few %
CAPACITORS - ceramic	10^{14} n.cm^{-2}	Capacitance decrease of approx. 1% and power factor decrease approx. - 0·1%
	10^{18} n.cm^{-2}	Negligible changes.
	5×10^{16} n.cm^{-2} and 5×10^{15} gamma cm^{-2}	No detectable integrated effect in capacitance ; rate effect may be - 5% capacitance change.
RESISTORS - wire-wound	$+3{\cdot}6 \times 10^{16}$ n.cm^{-2} and $+3{\cdot}6 \times 10^{15}$ gamma cm^{-2}	Resistance change less than 0·5%
RESISTORS - carbon	10^{18} n.cm^{-2} and 10^{17} gamma cm^{-2}	Resistance decrease of few % and rate effect negligible
VALVES	$+10^{17}$ n.cm^{-2}	Some fail due to glass damage by 10^{17} n.cm^{-2}, others show no apparent damage by 10^{18} n.cm^{-2}
TELEVISION TUBES	Approx. 10^{11} n.cm^{-2} sec^{-1} and 10^{11} gamma cm^{-2} sec^{-1}	Considerable increase in dark current (rate effect) ; integrated effect negligible apart from glass darkening
PLASTIC INSULANTS	Approx. 10^{17} n.cm^{-2} or + 5·10^{7} rad	Considerable changes in mechanical properties of most plastics. Insulation resistance may decrease by a factor of 10^3
SEMI-CONDUCTOR DEVICES	10^{13} to 10^{16} n.cm^{-2}	Germanium diodes tend to become ohmic, and resistance and leakage currents may increase by several hundred %. Silicon diodes show high leakage currents and increases in back and forward resistances. Loss of amplification in germanium transistors by 10^{14} n.cm^{-2}
GLASS	10^{14} n.cm^{-2} or 10^7 rad	Discolouration

value given by the integrated-effect for the flux received. This implies that component properties measured before and after irradiation are not necessarily representative of actual values during irradiation. The magnitudes of rate-effects vary from component to component.

Although circuitry must be a minimum, it is necessary to provide sufficient head amplifier gain to raise the camera tube output signal level sufficiently for it to be passed to the control equipment over several hundred feet of cable, without suffering from the pick-up of any spurious signals. Since the camera may be called to observe fine detail in the structure within the reactor, a satisfactory bandwidth of at least 5 Mc/s must be maintained throughout the amplifier, and the output passed to the camera control unit from a suitably low impedance source. It is also desirable to achieve this performance with the minimum anode supply voltage, so that all capacitors employed have working voltages which give good safety factors, despite the temperature rise derating required, without the need to employ unduly large components.

Nuclear Technology Materials

Measuring stored energy in irradiated graphite

THE WAY in which stored energy is released from irradiated graphite depends on the properties of the graphite and on the conditions under which the release takes place. In an experiment on stored energy these conditions may be specified either by the time-temperature relation or by a heat transfer condition. A calorimeter intended for measuring stored energy release with given heat transfer conditions is described by R.W. Henson and J.H.W. Simmons in UKAEA report No. AERE M/R 2564. This type of measurement can be used to predict the behaviour of stored energy released during an annealing operation on a reactor.

The release of stored energy is a complex process and its kinetics are not understood in detail. For many purposes, however, it is possible to make use of the rate equation

$$\frac{dS}{dt} = - f(S) \exp(-A(S)/T) \quad (1)$$

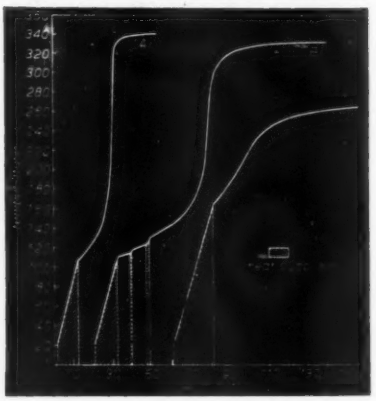
where T is the absolute temperature and S the amount of stored energy remaining at a time t. The heat transfer condition which has to be taken with this equation is:

$$s\frac{dT}{dt} = \frac{dS}{dt} + h(T, t) \quad (2)$$

where $s(T)$ is the specific heat of graphite at temperature T. The object of this type of experiment is to carry out a measurement with a given form for the function $h(T, t)$. It is not, in practice, possible to obtain the required condition exactly. The procedure adopted is to carry out an experiment in which $h(T, t)$ approximates to the intended value $h_p(T, t)$. The true value of $h(T, t)$ is then determined after the experiment. Thus, the measurement of stored energy entails a measurement of temperature as a function of time with $h(T, t)$ approximating to a given $h_p(T, t)$ together with the determination of the correct value of $h(T, t)$.

One condition which is used is $h_p = 0$. This is the adiabatic rise method. The sample is placed in an enclosure, the temperature of which is maintained at all times close to the temperature of the sample. The thermal insulation between the sample and the calorimeter is made as good as possible. A small radiant heater, consisting of a coil of platinum wire, is placed in the enclosure. By this means the temperature of the sample is raised as quickly as possible to the 'starting temperature'. The heat supply is then cut off and the temperature of the sample and calorimeter rises due to the release of stored energy. By measuring the rise in temperature the amount of stored energy released can be determined from the known specific heat of graphite. A correction is applied for the heat gained or lost.

Typical adiabatic release curves are shown in the diagram for a high energy sample (A) and a low energy sample (B). Curve (B) shows how the starting temperature may be raised in steps until a suitable starting rate is obtained. The curves show that at times the calorimeter has to follow a slow drift during which an accurate temperature control is needed to keep the heat transfer small. At other times there may be a rapid temperature rise and the calorimeter must be able to follow this without lagging or over-shooting.



Typical adiabatic release curves. (B) shows how the starting temperature may be raised in steps until a suitable rate of rise is obtained

By controlling the temperature of the enclosure a specified amount above or below that of the sample, it is possible to introduce a known heat gain or loss to the sample. By this means stored energy can be measured with various forms for the function $h(T, t)$.

The report gives full details of the calorimeter and its electronic control together with details of the experimental method.

Evaluation of heat transfer surfaces for nuclear boilers

Part 2 Finned tubing

by B. G. EDISS, A.M.I.Mech.E., A.R.T.C.S.
and R. BILSBOROUGH, D.L.C. (Chem. Eng.)
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Following last month's discussion of plain tubing, this concluding article shows the overwhelming advantage of finned surfaces and analyses the effect of fin dimensions on the cost of power generated

When the thermal resistance on the inside of a metal tube is much lower than that on the outside, as when steam is generated in a pipe by a hot gas or when steam condensing in a pipe is being used to heat air, externally finned surfaces or extended surfaces are of value in increasing substantially the rate of heat transfer per unit length of tube.

Bearing this in mind, a power loss in tube length calculation was carried out, on the same lines as that for plain tubes, for a tube already in commercial production by Tube Products Ltd. of Oldbury. The results of this calculation are shown in Figure 12. Comparison of this curve with the corresponding one for plain tube in 'staggered' formation (Figure 10 last month) shows an overwhelming advantage in favour of the finned tubing. It must be borne in mind however at this stage that extended surface is necessarily more expensive per foot than plain tube.

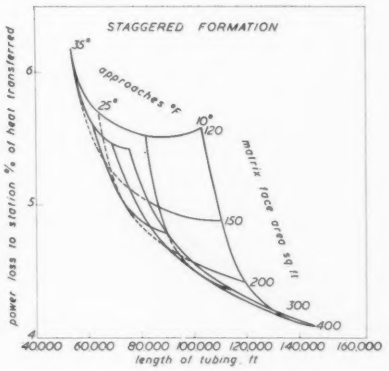
Since there is no reason to believe that the extended surface used for the comparison was the ideal for the conditions, it was considered that some attempt should be made to design a fin of the optimum geometry.

Design of transverse fins

M. Jakob (5) derives the equations that give the proportions of the straight fin requiring the least material. According to these equations the most favourable proportions are those of a fin whose profile is confined by parabolas. Unfortunately, this profile is far too delicate at the tip for manufacturing and practical use. Other profiles, which give as closely as possible the condition of least material, must be considered. It is found that a fin with triangular profile requires only a further 5% of material whilst its length is 84·2% and its base thickness 82·8% of that of the parabolic profile fin. Even now the profile at the tip is too delicate for manufacturing and practical use. It is the straight fin of rectangular profile which yields results of practical value whose length is 79·8% and its base thickness 63·2% of that of the parabolic profile fin, yet requiring 51·5% more material.

The most favourable thickness of the rectangular fin which requires the least material is given as (5) :

$$2y_o = 2\left[\frac{\frac{h}{k}a_L^2}{\mu_f^2}\right]^{0\cdot3}$$



Relations of power loss to length of finned tube by Tube Products Ltd. in stagged formation. Tube dimensions were: o.d. 2·002in., i d. 1·646in., fin ht. 0·409in., fin thickness 0·057in., no of fins 64/ft, transverse pitch 4 1/16 in., longitudinal pitch 2½in. (Fig. 12)

Jakob further states μ_f to be 1·4192. Considering only ferrous materials suitable for cold forming or welding with k=26 Btu/h ft ^{2} °F/ft then,

$$2y_o = 2(0\cdot0192)^{0\cdot3}\ h^{0\cdot3}\ a_L^{0\cdot6}$$

Put $2y_o = T$, the fin thickness (ft)

L = the fin height (ft)

h = h_o, the outside film coefficient (Btu/h ft^2 °F)

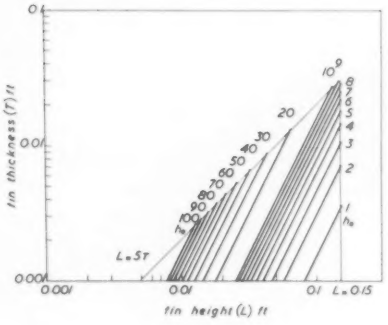
then $a_L = TL$

and $T = 2(0\cdot0192)^{0\cdot3} h_o^{0\cdot3} T^{0\cdot6} L^{0\cdot6}$

$$= 0\cdot1528\ h_o\ L^2 \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

In the derivation of the foregoing expression, Jakob considered an infinite rod whose thickness was so small compared with its height that temperature gradients across the width of the fin could be neglected. So as not to invalidate this assumption, an arbitary limit that L be not less than 5T is imposed. Obviously that which holds for an infinite rod is valid also for a fin.

The fin proportions must be such that they can be manufactured fairly easily and that they give a size of matrix which is not embarrassing. It could not be hoped to produce fins 0·0026 ft high and 0·000001 ft thick or 1·0 ft high and 0·16 ft thick. The fin proportions must be concomitant with good engineering practice. Accordingly, the following conditions have been imposed :



Relationship between fin thickness T and fin height L for various values of h_o, the outside film coefficient (Fig. 13)

a. the fin height L must never exceed 0·15 ft
b. the fin thickness T must never be less than 0·001 ft

Equation (1), plotted with the above three impositions, is shown in Figure 13 and gives, for any value of h_o, the relationship between L and T.

Efficiency of extended surfaces

Gardener (6) gives efficiencies for various forms of extended surface. His Figure 5 shows fin efficiency Φ plotted against $W(h/ky_b)^{1/2}$ for annular fins of constant thickness.

Replacing Gardener's symbols :

$$W\left[\frac{h}{k y_b}\right]^{1/2} = L\frac{h_o}{26}\quad\frac{T}{2}^{1/2}$$

and replacing T by $0\cdot1528\ h_o\ L^2$ to give the most favourable proportions of fin, this expression reduces to 0·71, showing that fins of the most favourable proportions operate with a constant value of

$$W\left[\frac{h}{k y_b}\right]^{1/2} = 0\cdot71$$

and that their efficiencies vary only as the ratio X_e/X_b.

The outside film coefficient is referred to the inside surface by the expression :

$$h_{oi} = \frac{h_o}{A_i}(A_f\ \Phi\ A_e)$$

where A_f = fin surface per foot (excluding fin tips) (ft^2/ft)

A_o = surface area of the plain tube portion (ft^2/ft)

A_i = inside surface of tube (ft^2/ft)

Φ = fin efficiency for a constant value of $W(h/ky_b)^{1/2} = 0\cdot71$

The value of h_o selected from Figure 12 may now be converted to a value of h_{oi}.

The correlation proposed by Jameson (7) is chosen to relate outside heat transfer coefficient to gas flow and tube configuration. This correlation has been converted to the Sieder and Tate heat transfer factor with the factor of the viscosity correction Φ taken as unity for gases.

The equivalent diameter in Jameson's correlation is defined as :

$$D_e = \frac{2(A_f+A_o)}{\pi\ (\text{projected perimeter})}$$

From Jameson :

$$h_o = 0\cdot0918\frac{k}{D_e}\ Re^{0\cdot723}Pr^{0\cdot3}$$

$$= 0\cdot0918\ \frac{k Pr^{0\cdot3}}{\mu^{0\cdot723}}\ \frac{G^{0\cdot723}}{D_e^{0\cdot277}}$$

therefore $G^{0\cdot723} = F\ h_o\ D_e^{0\cdot277}$

where $F = \dfrac{\mu^{0\cdot723}}{0\cdot0918\ k\ Pr^{0\cdot3}}$

In order to compile equivalent matrices, a standard basis of temperature and pressure for the gas must be used. For this purpose a pressure of 10 atmospheres, an average temperature of 800°F, and a fixed quantity of gas have been selected. At this temperature and pressure the coefficient F is evaluated and the expression reduces to :

$$G = 305\ h_o^{1\cdot383}\ D_e^{0\cdot3831}$$

The following correlation for pressure drop, over extended surfaces by Gunter and Shaw (8) is used :

$$\Delta P = \frac{f G^2 L}{2\ g\ D_v \rho}\left[\frac{\mu_w}{\mu}\right]^{0\cdot4}\left[\frac{D_v}{S_T}\right]^{0\cdot4}\left[\frac{S_L}{S_T}\right]^{0\cdot6}$$

Taking the value of the viscosity correction ratio $\left(\mu_w/\mu\right)^{0\cdot4}$ to be unity for gases, then,

$$\Delta P\,(psi) = \frac{f G^2 L}{7.5.10^{12} D_v S}\left[\frac{D_v}{S_T}\right]^{0\cdot4}\left[\frac{S_L}{S_T}\right]^{0\cdot6}$$

where S is the specific gravity of the gas referred to water. From Gunter and Shaw's paper (8), Figure 5, we find, for Reynold's numbers in excess of 500, the

relationship between the Reynold's number and the friction factor to be :

$$f = 1 \cdot 92 \ Re^{-0 \cdot 145}$$

Since the above expression is a statistical regression it is felt advisable to incorporate a factor of safety. Accordingly the coefficient 1·92 is replaced by one 10% greater, i.e. 2·11.

Therefore $f = 2 \cdot 11 \ Re^{-0 \cdot 145}$

$$\therefore \ \Delta P \text{ (psi)} = \frac{2 \cdot 11 Re^{-0 \cdot 145} G^2 L}{7.50.\ 10^{12} D_v \ S} \left[\frac{D_v}{S_T}\right]^{0 \cdot 4} \left[\frac{S_L}{S_T}\right]^{0 \cdot 6}$$

$$= \frac{2 \cdot 81\ 10^{-13} \mu^{0 \cdot 145} G^{1 \cdot 855} \ L \ S_L{}^{0 \cdot 6}}{S \ D_v{}^{0 \cdot 745} \ S_T}$$

$$\therefore \ \Delta P \text{ (psi/row)} = \frac{2 \cdot 81\ 10^{-13} \mu^{0 \cdot 145} G^{1 \cdot 855} S_v S_L{}^{0 \cdot 6}}{S \ D_v{}^{0 \cdot 745} \ S_T}$$

where :

μ = gas viscosity (lb/ft.h)

G = gas mass velocity based on minimum net flow area (lb/ft^2 h)

S_L = centre to centre distance from a tube in one row to the nearest tube in the next transverse row (ft)

S_T = transverse pitch (centre to centre distance from tube to tube in one transverse row) (ft)

Sv = the vertical pitch which corresponds with S_L and S_T (ft)

S = gas specific gravity (referred to water)

D_v = volumetric hydraulic diameter of bank (ft)

$$= \frac{4 \text{ (net free volume)}}{\text{friction surface}}$$

At the reference pressure and temperature, the physical constants and transport properties may be evaluated. Therefore,

$$\Delta P \text{ (psi/row)} = \frac{2 \cdot 5\ 10^{-11} S_L{}^{0 \cdot 6} S_v G^{1 \cdot 855}}{D_v{}^{0 \cdot 745} \ S_T}$$

This expression for pressure drop is applicable to both staggered and in line formations. For staggered formation, since the pressure drop is calculated from the values of S_v, $D_v{}^{0 \cdot 745}$, and the value of G obtained from the minimum net flow area, there is no significant change in the pressure drop as S_v decreases, other parameters being kept constant, until the value of the velocity in the diagonal pitch becomes greater than that in the transverse pitch. With the value of S_v decreased further, the minimum net flow area occurs in the diagonal pitch, and the pressure drop must be calculated accordingly. Due to the increased value of G the pressure drop increases rapidly.

In selecting a value of S_v for any given value of S_T, two criteria must be borne in mind, namely, minimum pressure drop with minimum matrix volume. To satisfy these conditions the value of S_v should be chosen to give equal velocities. If comparison be made between staggered and in line formation, for equal values of S_T and for the vertical pitch of the in line formation equal to the diagonal pitch of the staggered formation, the area of heat transfer surface required is the same in both instances. The pressure drop, however, is larger, and for equal amounts of surface the matrix volume is also larger for in line formation.

If the comparison be extended such that the value of S_T in in line formation be progressively reduced until a minimum is reached, this minimum occurs when $S_T = S_L$; then the gas mass velocity is progressively increased until finally, at $S_T = S_L$, it is doubled. The outside heat transfer coefficient increases by the ratio $(G_2/G_1)^{0 \cdot 723} = 2^{0 \cdot 723} = 1 \cdot 65$. Hence the amount of surface required is reduced by something less than this figure. The pressure drop increases by a factor somewhat greater than $(G_2/G_1)^{1 \cdot 855} = 2^{1 \cdot 855} = 3 \cdot 6$ since both S_T and D_v decrease as S_T decreases.

Since the pressure drop for the minimum case of in line formation is so much greater than the minimum case of staggered formation, the matrix volume also being greater, staggered formation is to be preferred. Henceforth, staggered formation with the velocity in the diagonal pitch equal to that in the transverse pitch only will be considered, with the value of S_L at its minimum. A further arbitary condition is imposed in that the minimum distance between the fin tips of two adjacent tubes is fixed at some figure depending upon tolerances, etc.

In order to determine the pressure drop, the volumetric hydraulic diameter D_v must be known ; incorporated in D_v is the net free volume of the matrix, and, to obtain this, both the transverse and longitudinal pitches are required. For any particular tube geometry the value of the diagonal pitch S_L is known, from which the value of S_T can be calculated to give equal gas velocities in both pitches, and hence S_v. From the values obtained for S_v, S_L, S_T the value of D_v follows. The pressure drop per row may now be found.

To compile matrices for equivalent heat duties, the total quantity of gas has been fixed between certain temperature limits, and the mean temperature difference has also been fixed. Knowing the total quantity of gas, with the value of G calculated previously the flow area is obtainable. With the geometry of the tube and the transverse pitch known, the matrix face area is calculated.

Survey of power costs

The overall heat transfer coefficient is known, since the inside coefficient remains constant at its relevant value, the metal resistance follows from the tube geometry, and h_{oi} has already been calculated. The amount of heat transfer surface (basis inside diameter) required for the fixed conditions of heat load and LMTD, may be determined from the classical expression attributed to Fourier :

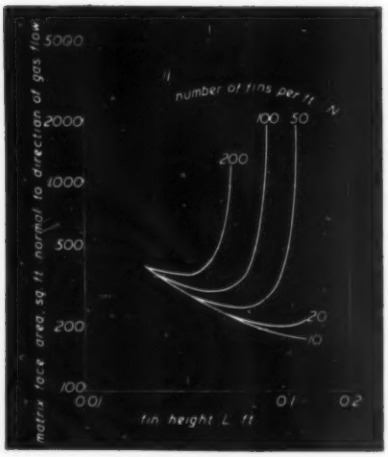
$$Q = U \ . \ A. \ LMTD$$

From A and the tube geometry, flow area, and the

value of the transverse pitch, the number of rows deep in the matrix may be calculated,

$$R = \frac{A\ G\ (S_T - \text{projected area/ft of tube})}{W\ \pi\ d}$$

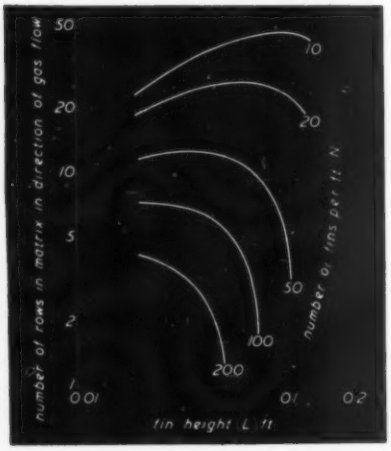
Hence the pressure drop over the matrix may be calculated from the pressure drop per row and the number of rows. From the foregoing it is a simple matter to



Matrix face area normal to gas flow for various values of fin height, L, with outside heat transfer coefficient, h_o, fixed at 10 Btu/h sq. ft. °F (Fig. 14)

calculate the length of tube in the matrix, and the size of shell required to house the matrix, if the matrix area be assumed to occupy 75% of the shell cross-sectional area.

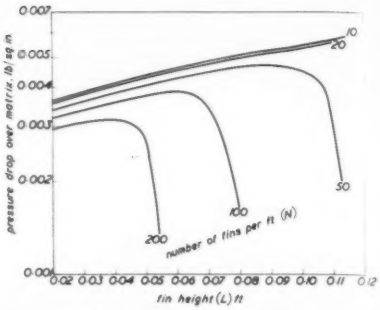
Using the method outlined, it is possible to formulate a programme such that for a range of values of



Number of rows in matrix for varying fin height with h_o fixed at 10 (Fig. 15)

h_o and a range of values of L and N the matrix dimensions are obtained, with its attendant pressure drop. Using this information an economic survey may be undertaken.

For a comprehensive economic survey to be carried out, the cost of pressure vessels must be known for a wide range of the ratio length/diameter and also the price of extended surface over the range considered and the cost of fittings etc. associated with the matrix.

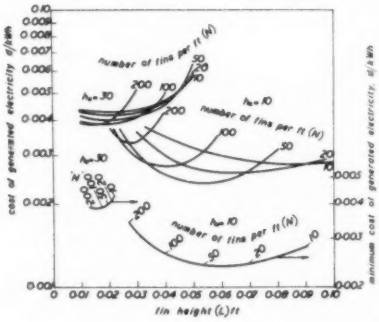


Pressure drop over matrix for varying fin height with h_o fixed at 10 (Fig. 16)

The pressure drop over the matrix only need be considered. All the above capital cost is that which must be amortized at a suitable rate over a suitable period of time, and expressed as a cost per unit of generated electricity. The only other factor necessary for the complete survey is the cost of the power required to drive the circulatory equipment to overcome the pressure drop over the matrix only.

Figures 14, 15 and 16 show the various sizes of matrices obtained for a value of the outside heat transfer coefficient of 10 Btu/h $^{\circ}$F ft^2 for various values of the fin height L and any value of N number of fins per foot, and the pressure drop over the corresponding matrix.

Figure 17 shows some of the results of an economic survey undertaken by the authors. The upper two families of curves show the variation in the cost of generated electricity for ranges of L and N for values of



Influence of fin height on cost of electricity generated (Fig. 17)

h_o of 10 and 30. The lower two curves show the minimum costs associated with each value of L and N.

Higher values of h_o show progressive increase in costs. It is interesting to note that the minimum cost is obtained using a fin whose proportions are L = 0·06 ft, N = 40 fins per ft, and T = 0·0055 ft.

In analysing the results, sound engineering judgment must be used. With an h_o of 10 the generation costs are very low but the associated capital is large ; at higher values of h_o the generation costs are higher with a reduction in capital. The generation costs shown are relevant to boilers only, and should not be confused with nuclear power station running costs.

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6. Gardner, K.A. Trans. A.S.M.E. 1945, 67, p.621 - 32
7. Jameson, S.L. Trans. A.S.M.E. 1945, 67, p.633 - 42
8. Gunter, A.Y. and Shaw, W.A. Trans. A.S.M.E. 1945, 67, p.643 - 60

Cross Section by GRACCHUS

ATOMIC Power Constructions has had its share of difficulties in the last two years. To be a power station-building consortium without a station to build is embarrassing enough, but to be the new boy can be awkward anyway, as they discovered on the BICEP piles at Harwell. Coming along late they found the programme organized and running nicely without them, and only now have they managed to get something like equality of status - though a new committee has had to be set up to get round the problem.

Going back a bit, BICEP British Industrial Co-operative Exponential Programme - was started to give the consortia facilities for basic experimental work on fuels, and the bulk of its equipment is four exponential stacks. By playing about with different lattice spacings and fuels useful quantities like k_∞, p and f can be worked out for various systems. The whole thing is run under the NPCC - Nuclear Power Collaborative Committee - which was formed by the original four consortia, and the actual programme is determined by RPWP - Reactor Physics Working Party. The experimental team includes one man from each group, plus - as one might almost expect - another from Babcock & Wilcox, who like to keep their independence. When APC was formed they were invited to send a man to join the team and were allowed on the BICEP executive meetings, but not on the NPCC or the RPWP. This meant that not only were they denied access to RPWP literature accumulated before their arrival, which was perhaps fair enough, but were kept firmly in their place as the odd group out, which was not. The situation has now been largely resolved by the formation of yet another committee to control the experimental programme. This one is called BPWP - Basic Physics Working Party - and APC is on it. The RPWP seems to have been superseded and what will happen to it is not clear. Perhaps it will just fade quietly away.

Incidentally APC deserve congratulations for the Trawsfynydd tender. The invitation contained anti-price cutting clauses which ensured that the order did not necessarily have to go to the lowest tender, so apparently their design could not be faulted.

●

The General Electric Company's work on ship reactors looks interesting. With the agreement with MAN of Nuremburg in their pockets ('Worldview,' July) and a lot of hard work behind them, the team under Michael Hartnell-Beavis has got out a design for a 50,000 ton tanker which they say could be built for £M2 (excluding turbines) and operate for 0·2d a shaft horsepower hour (assuming an equilibrium fuel cycle and US fuel prices). Their proposals for the Galbraith committee had to be frozen at a fairly early stage - though even these were made over a year after the AEA's now defunct AGR ship study and the present design has moved on considerably. They are being very cagey about the uranium dioxide fuel element but I gather it is a little longer than the Hunterston type and not a bundle. 162 of the 18, 3% enriched, elements are used to give a net 55MW heat. Size of the reactor is down to 92 x 35 x 37ft, with a total weight of 1983 tons. I had a chance to look at the drawings recently and the lay-out looks extremely neat. A separate standpipe is provided for each channel and the charge machine design is very compact. The reactor is admittedly not yet competitive, with its stainless steel canning, but the big hope for the future is, of course, impermeable graphite.

●

THE AEA is still trying to discourage the use of morbid language by its staff. One of its recent internal memos reads : 'It is the policy of the AEA and the BSI to avoid the use of "graveyard" expressions. In future therefore, will you please ensure that "shielding flasks" are not called "coffins" but always "flasks". Similarly the term "mortuary holes" should be abandoned in favour of, say, "storage holes". The motive behind all this stuffiness is quite laudable - the Authority feels that public reaction to atomic energy is sufficiently nervous and irrational without gratuitously throwing macabre expressions about. But I doubt whether it will stop its depraved engineers and scientists using their favourite terms or even thinking up some more picturesque and horrible yet. The attempt in certain quarters to stamp on those slugs and force 'fission product detection equipment' into common usage seems to have failed. At any rate one still hears 'burst slug detection gear' much more often - though 'burst can detection gear' seems to be gaining ground, and we always have the American 'failed element gear' May I suggest standardizing on 'failed slug detection gear' ?

●

Good radioactive waste disposal means good public relations and I find that the AEA have developed an unexpectedly keen nose for this. Having got myself mixed up with the recent press visit to Winfrith I was rather surprised when the tour included a half-hour journey to the effluent pipe outlet on the coast. There was nothing to see except a dozen lengths of pipe, but coachload after coachload of journalists arrived and had to stand around for half an hour or more. I wondered what the point was. I saw it next day. Nearly all the newspapers carried long stories on the effluent disposal arrangements. The establishment itself rated only a line or two.

New Product Survey

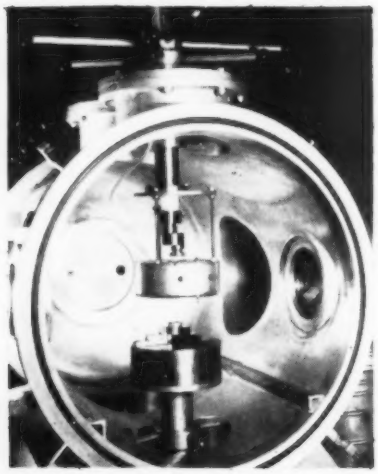
PLANT · EQUIPMENT · INSTRUMENTS · MATERIALS

ELECTRON WELDING

first machine in UK

The possibility of using a beam of electrons to provide precision welding in vacuo was first realized by J. A. Stohr of the French CEA (see NUCLEAR POWER June 1958, p 272) and equipment based on this work is now being manufactured under licence by Edwards High Vacuum Ltd. The first model introduced is known as the Speedivac Model EB2 which is intended to provide the research worker with a robust, efficient and versatile tool for the thorough investigation of electron welding techniques. It is designed on the unit construction principle and consists basically of a vacuum work chamber, electron gun assembly, work holder, vacuum pumping system, d.c. power supply and pulsing unit.

The work chamber (10 mm Hg) is provided with ports both for visual observation of welding and for the fitting of the electron gun in both the vertical and horizontal positions. Provision is made for both electrostatic and magnetic focusing and as the more flexible of these two techniques is magnetic focusing, the electron gun is equipped with a magnetic lens, the field strength of which may be externally adjusted to provide a considerable range of adjustment of the electron spot.



In the Edwards beam welder a simple means of lining up the electron beam is provided by means of eccentric rotation

The plant is equipped for circumferential welding, the workpiece to be welded being held in a chuck driven by an external variable speed motor. To enable long tubes to be welded the rotating mechanism is provided with a removable base cap so that the workpiece can be loaded externally through the base of the chuck. Provision is also made for the future addition of longitudinal traverse mechanisms.

It may be desirable in some instances to pulse the beam during the welding operation (for example, the obtaining of deep penetration with a restriction of heating effect). This is achieved either by interrupting the high tension accelerating voltage or by applying a bias potential to the screen of the electron gun sufficient to suppress completely the electron emission and to ensure full flexibility for research work both methods of pulsing are provided.

The maximum degree of safety is ensured by earthing the positive pole of the d.c. supply and running the specimen to be welded at earth potential. The whole of the exterior of the electron gun is also earth shielded whilst a vacuum switch ensures that the high tension supply cannot be operated until a low pressure has been created within the chamber.

The observation windows are fitted with lead glass screens to protect the operator from the soft X-rays produced when working up to the maximum voltage of 20 kV. Tests carried out have shown that the plant can be safely operated for a maximum of 30 hours per week at 20 kV without the lead glass screens.

Tick **No 208** on reply card

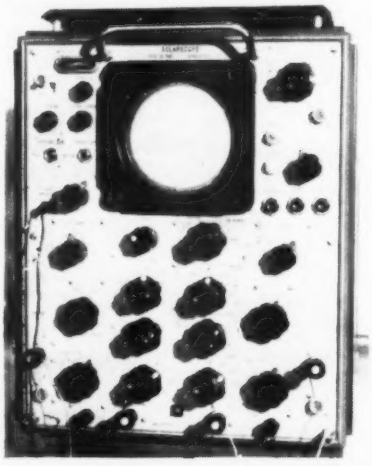
MEMOTRON OSCILLOSCOPE

trapping the transient

The new Solartron Infinite Persistence Oscilloscope, type QD910, enables transient phenomena to be arrested and studied by freezing non-recurrent waveforms and other types of curves on an oscilloscope screen for as long as may be desired. It employs a *Memotron* storage cathode-ray tube which gives an infinite trace persistence. The trace is immediately erasable after each investigation is completed.

The QD910 is a dual-channel instrument, each channel having a bandwidth of d.c. to 1 Mc/s. The comprehensive user facilities provided are similar to those found in an advanced general-purpose oscilloscope—thus the IPO can be employed in all cases where continuous photographic recording from an oscilloscope was formerly necessary.

The Memotron tube contains an orthodox 'writing' gun and deflector plate assembly with an acceleration potential of 3 kV and a medium persistence viewing screen with a potential of +3 kV applied to it. Behind the viewing screen are two fine wire meshes which are the collector and storing meshes. The first, which is adjacent to the viewing screen, has a coating on the far side of a dielectric material, which has a secondary-emission coefficient, and is normally at zero potential. The collector mesh is set at +160 V. A second gun, the flood gun, is mounted to the side of the deflector plates and floods the screen of the tube with slow electrons. When the writing gun is cut off flood electrons leak through the storage mesh and are attracted to the viewing screen where they produce a dull uniform illumination of the screen. When the writing gun is turned on and deflector voltages are applied to the plates of the tube, the fast moving electrons from the gun strike the storage mesh and produce secondary electrons from the dielectric coating. The area thus written upon loses more secondary electrons than it gains primary ones, thus making positive charges which attract flood electrons, which in turn pass through the mesh and are attracted to the highly positive viewing screen reproducing on it the pattern written on the mesh.

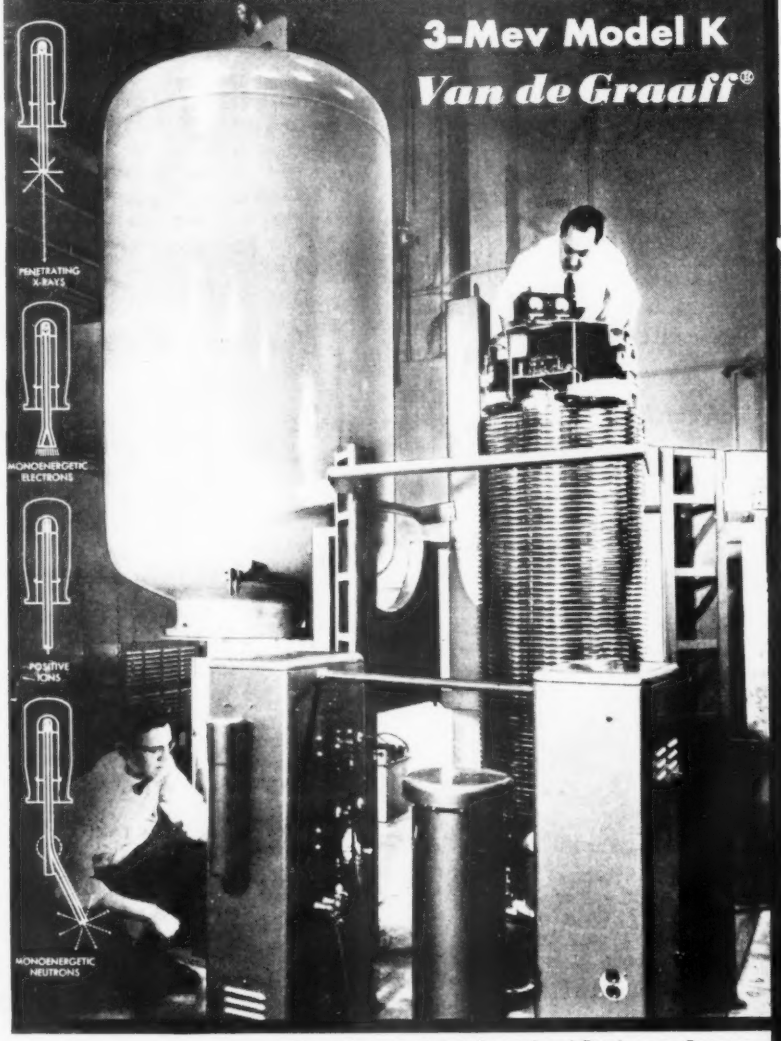


The oscilloscope has provision for external brilliance ('Z') modulation of the time-base waveforms and delay pulses are brought out on the front panel. An internally-generated waveform provides automatic erasing for initial setting of the tube controls, such as focus or shift

The flood gun maintains the positive charge on the storage mesh indefinitely. Once a given area has risen above a certain potential level, it accelerates the flood electrons sufficiently to release further secondary electrons, and thus its potential continues to rise until it approaches that of the collector mesh, at which potential it stabilizes. Thus the positive charge pattern is maintained. To erase the picture, the potential of the collector mesh is lowered for a short interval. To erase the picture, the potential

Versatile Research Accelerator

3-Mev Model K *Van de Graaff*®



Photos Courtesy of Gulf Research and Development Company

This powerful multi-particle accelerator — proved in the field — is the basic tool for a broad program of fundamental or applied radiation research.

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- Polymerization
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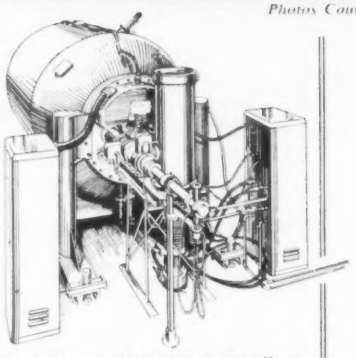
- Radiography



The 3-Mev, Model K Van de Graaff can be furnished for horizontal installation as illustrated above.

ELECTRONS:
1 microampere to 1 milliampere. (Use of maximum current requires beam scanning).

X-RAYS:
900 R per minute at one meter. (Equivalent to 20,000 curies of Cobalt-60).

POSITIVE IONS:
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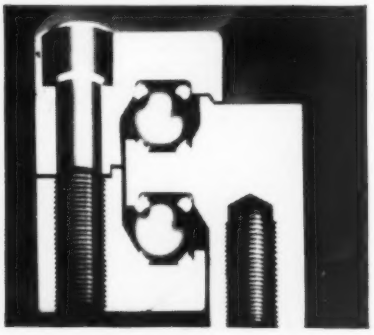
of the collector mesh is lowered for a short interval. Secondary electrons then fall back on to the collector mesh, and cancel the positive charges.

Tick **No 209** on reply card

ANTI-FRICTION BEARINGS
for atomic reactors

A solution to certain bearing problems is provided by a new type of anti-friction bearing which uses hardened wires for the ball tracks. Manufactured by Roballo Engineering of London, it is designed to carry axial loads, radial forces and tilting moments in a single unit, and thus replaces systems incorporating a kingpin or centre pivot, and leaves the centre space free for other essential parts. The rolling elements run on high tensile spring steel wires, which are seated in accurately machined grooves. This avoids the costly grinding necessary to rectify distortion on large diameter rings after flame hardening, and



The rolling elements of the bearings are kept at their correct pitch by cages, separators or spacer balls, according to the load/duty conditions

enables the bearings to be easily and precisely adjusted to eliminate all play.

The unique 'rolling in' process during manufacture both hardens the surfaces of the wires and forms them to the curvature of the balls. The four areas of contact so produced (compared with two points of contact in ordinary ball bearings) give this type of bearing its ability to carry high loads in both axial and radial directions.

The wire rings are not continuous—a gap of 0·02 in. to 0·08 in. being left—so that they fit precisely round the entire circumference of the bearing ring, thus automatically compensating for any variation in length due to an increase or decrease in temperature. This gap does not in any way impair the load carrying capacity of the bearing due to the large number of rolling elements, nor does it detract from the bearings, smooth running performance.

Size of bearings ranges up to 13 ft in diameter in one piece, and up to 45 ft in segments. They are suitable for use as slewing rings carrying axial loads up to 1000 tons or even more, or as continuous rotating bearings where surface speeds do not exceed 65 ft/s.

The bearing balls are of high quality, special alloy steel. The backing rings can be made of any suitable material, e.g. cast iron, stainless steel, light alloy or even plastic. Internal or external spur gearing to suit individual requirements can be directly machined onto one of the rings to accept a drive for the rotating machinery. Rings are held together by high tensile bolts spaced equidistant about the ring and tapped into the upper or lower ring.

One application envisaged by the firm for these new bearings is in reactor fuelling machines.

Tick **No 210** on reply card

DECIMAL INDICATOR TUBE
for high speed counting

Mullard have introduced a cold cathode decimal indicator tube (type Z503M) for use in the high-speed stages of counting equipments.

In the slower-speed counting stages, decimal stepping tubes, which give a visual indication of the count, are used. But for high-speed counting conventional hard valves, or specialized tubes like the trochotron, are necessary, and these require some external indicating device.

It consists of an anode and ten cathodes, with each cathode brought-out to a separate pin so that ten connexions can be made to the counting circuit. The count is indicated by a glow discharge on the appropriate cathode. The tube gives 'end-on' viewing of the discharge, the position of which can be identified by an external numbered escutcheon. Recommended anode current for the tube is 60 microamps; the minimum anode-to-cathode voltage necessary for ignition is 129 V (with some ambient light); and the voltage across the tube and a 500 kilohm series resistor below which the glow will extinguish is 105 V.

The Z503M is mounted on a duodecal (B12A) base, and has a maximum seated height of 70 mm and a maximum diameter of 33 mm.

Tick **No 211** on reply card

THERMOCOUPLE TRIP AMPLIFIER
high stability and accuracy

A new fully-transistorized thermocouple trip amplifier, Type N642, is announced by Ekco Electronics. Primarily designed for use in nuclear reactor installations, it also has many industrial applications.

The Type N642 monitors the temperature at a specific point within the plant and trips external guard circuits by releasing an internal relay when the temperature reaches the pre-set trip level. This level is set by means of a ten-turn helical potentiometer with a dial directly calibrated in temperature. The high stability and accuracy of the trip setting is a special feature of the instrument. A 'low-margin' warning, also provided, releases a second internal relay and can be set at any point within the meter range, while the meter range can be supplied to order covering up to 100% of the ambient-to-trip-level range, with linear calibration.

Normally operated in conjunction with a chromel-alumel thermocouple, Type N642 can be used with other types with a slight modification. It covers the range 0–250°C and is fully 'fail-safe' with an indefinite life expectancy. A trip will also occur with an open-circuit thermocouple. The range of the instrument can be extended up to 1000°C to special order.

The amplifier requires an a.c. mains supply of 110 V–120 V or 200 V–250 V, 45–60 cycles (selected on a mains tapping panel). Four instruments can be installed side by side in a frame which fits a standard 19 in. rack.

A transistor chopper is incorporated in the input circuit, operating at approximately 700 c/s so that 50 c/s pick-up is rejected. This is followed by an amplifier and a detector which in turn releases the warning and trip circuits.

Tick **No 212** on reply card

IN BRIEF

Nitrogen generator. Birlec have a new range of nitrogen generators. A high degree of purification and a push-button startup mechanism are two of the salient features.

Tick **No 213** on reply card

Measuring instruments. Elomag of Brussels have three new instruments on the market. They are the *Transiscaler*, a small, compact portable scaler suitable for both laboratory and field work, the *Uranoscope*, a transistorized gamma radiation indicator, and the *Radiodigit* a pocket sized geiger-müller tube ratemeter.

Tick **No 214** on reply card

Stud welding. Crompton Parkinson's new TR3-3 power source is designed to provide all types of the company's machines with d.c. power necessary for studs up to ¾ in. dia.

Tick **No 215** on reply card

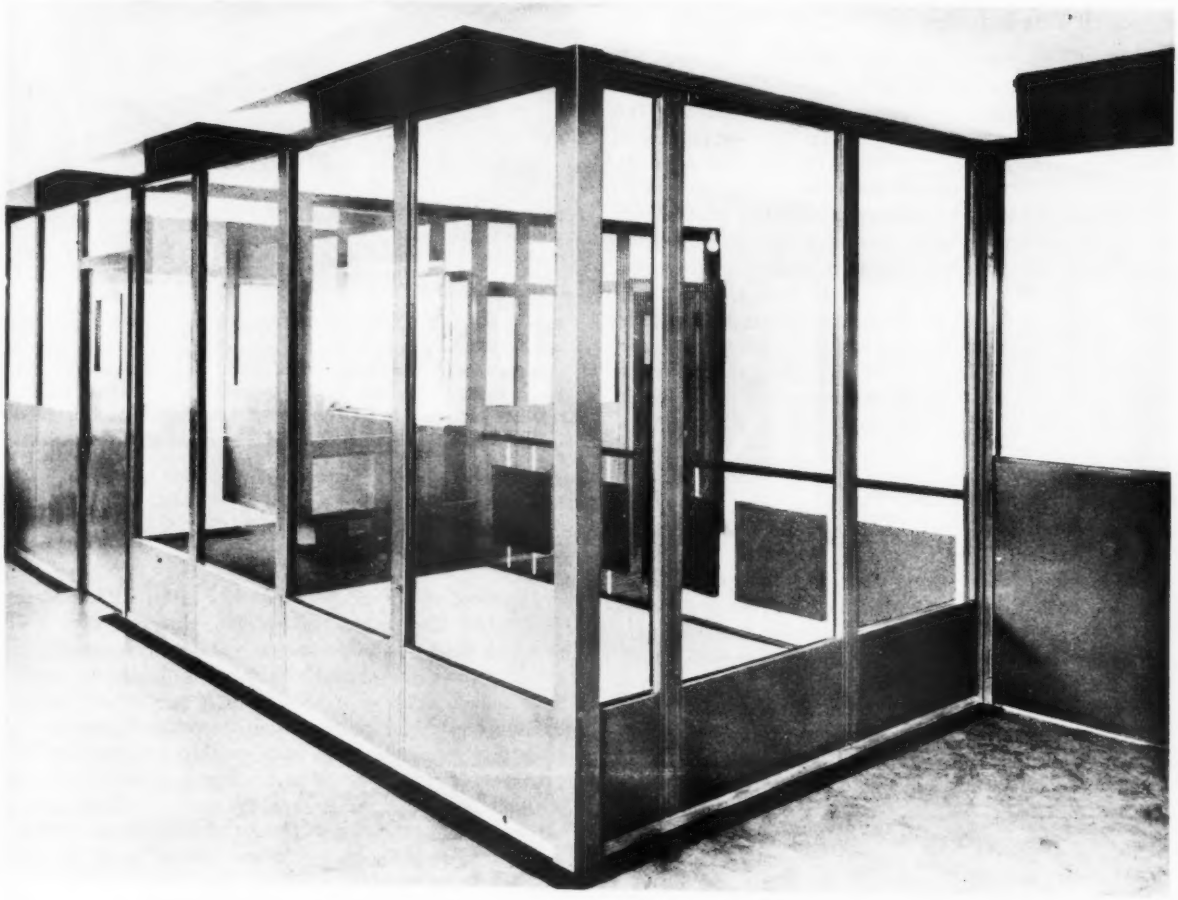
Magnetic crack detector. The firm of R. F. Fraser Smith announce a new portable model. Weighing 45 lb it gives an output of 750 amp. A change-over switch allows operation on 100/120 or 200/250 volt a.c. single-phase supply

Tick **No 216** on reply card

Swivel pipe joints. For hydraulic systems Avica Equipment's new range is for ¼ in ⅜ in. and ½ in. pipe lines.

Tick **No 217** on reply card

Bring light and calm to your office



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INDUSTRIAL NEWSDESK

Research aids industry

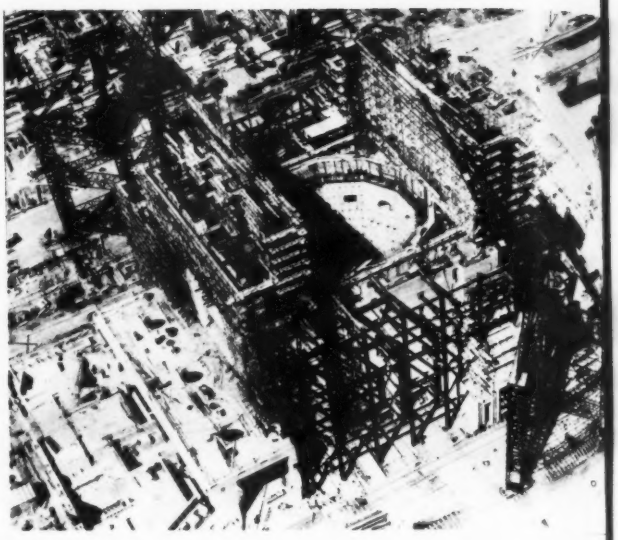
On July 14 the British Welding Research Association's (BWRA) establishment at Abington Hall held its open day. This provided an opportunity of evaluating the great assistance that BWRA gives to manufacturers. From a nuclear engineering point of view the most important work is that concerned with brittle fracture in welded 3 in. plates, employing a 2000 ton tensile test rig ; experimental stress analysis for fuel charging nozzles and similar duct entries in reactor containment pressure vessels ; and resistance welding, under contract for the AEA, of the dissimilar metals encountered when thermocouples have to be incorporated within nuclear fuel cans. Results of these and many other experiments are made available to members of BWRA in the form of confidential reports.

Franco-American fuel tie-up

Arrangements have been made by the US Sylvania-Corning Nuclear Corporation to purchase a share in the French nuclear fuel concern, Compagnie pour l'Etude et la Réalisation de Combustibles Atomiques (CERCA). This is the first commercial nuclear fuels production organization, with American and European participation, specifically set up to participate actively in the Euratom market. Research and manufacturing techniques will be shared under the agreement as soon as appropriate governmental approvals have been obtained. In this way, Sylvania-Corning Nuclear Corp. will become, with Saint Gobain, Peckiney and SFAC, joint owner of CERCA.

THREE YEARS TO GO

After 18 months at Hinkley Point, civil engineering on the 500MW English Electric/Babcock & Wilcox/Taylor Woodrow station is well advanced. The 400-ton Goliath crane is now operational, foundations for the turbine hall and pumping house (to the left of the two reactors) have been laid, and the cooling water outfall is substantially complete. In the foreground is the 90ft diameter intake caisson, now installed 2000ft off shore, through which water will flow at 35 million gallons per hour.



ONE HUNDRED FEET UP

Main biological shield of Hinkley's reactor 1, now complete, stands 100ft above ground level with the supplementary shields rising above it. The first two courses of the pressure vessel and the supporting skirt will shortly be moved into position from the fabrication area. On reactor 2 the shields are 50% complete.

Ready for more competition

At the end of June, Associated Electrical Industries completed the major part of the changes they have made to meet the increasingly competitive conditions, especially in overseas markets. Nine divisions, classified by products, will operate in place of AEI's subsidiary companies at home and abroad. It is anticipated that this reorganization will enable large-scale programmes of research and re-equipping to be carried out without overlapping between the individual divisions. Heavy plant, turbogenerator, transformer, electronic apparatus, switchgear, motor and control gear, Siemens Edison Swan cables, Siemens Edison Swan telecommunications and tractions will initially make up the divisions - others may be established later.

US firm goes European

During June, Mr. A. Gilles, Director of the Bank of Worms and President of Saphymo, a leading French nuclear instrumentation company, discussed plans with Tracerlab for the manufacture of their instrumentation in Europe. The American company has been investigating the capabilities and facilities of various European manufacturers and final arrangements with several of them are now being formulated.

Beryllium for Europe

The Imperial Smelting Corporation, UK subsidiary of the US Consolidated Zinc Corporation, and the Beryllium Corporation of Pennsylvania have formed a new company, Consolidated Beryllium Limited to produce nuclear grade beryllium and beryllium-copper for UK

what are the advantages of SINTOX alumina ceramics?

THE NUCLEAR CERAMIC

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These qualities have led to the use of SINTOX ceramics in many branches of engineering.
For the nuclear engineer a new grade of SINTOX—known as FF1—has been developed. In addition to its other attractive features, nuclear SINTOX has a low cross-section capture combined with compatibility with most materials used in reactor design. It is versatile in the production of a wide range of shapes and sizes and is particularly suitable for insulating parts in control gear and mechanical support members. White in colour, this new ceramic has already taken a leading place in the design and development of components for nuclear reactors.

STAS

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and European fabricators. The new company will operate the Imperial Smelting Corporation's plant at Avonmouth and plans are being prepared to meet increasing demand, estimated to reach some 100 tons annually by 1965, by additions to the existing plant. Work is starting immediately on a new plant, at Avonmouth, for the production of beryllium-copper master alloy. Arrangements have been made to meet any demand in excess of the UK output by material from the US Beryllium Corp at Reading, Pa.

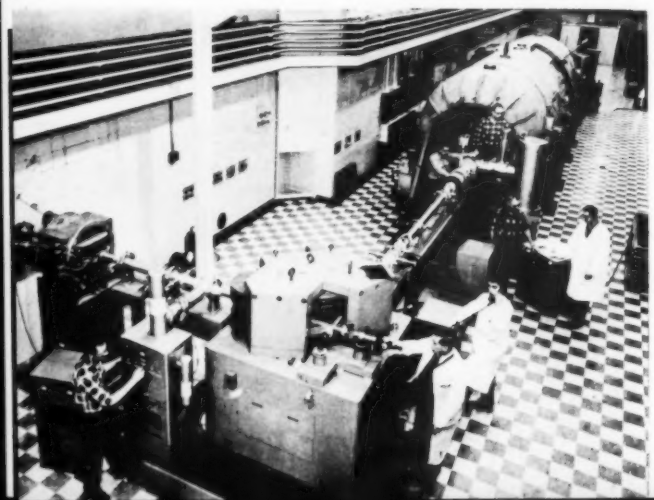
Developing new reactor steels

A joint programme by the United States Steel Corporation and General Electric is being undertaken to develop improved steels for use in nuclear power reactors. Aimed at producing higher strength alloy steels, particularly for use in boiling water reactor systems, one phase is investigating corrosion resistance under high temperature and pressure conditions and another phase, just starting, is studying high intensity neutron irradiation, using the GE's own test reactor. Steels with increased toughness to alleviate the chances of brittle fracture are being sought. Such material would lower reactor costs by enabling thinner walled vessels to be used.

New high temperature centre

So that industrial designers can more readily obtain data on the strength of high temperature materials, a Creep Information Centre is being set up at the National Engineering Laboratory (formerly the Mechanical Engineering Research Laboratory) at East Kilbride, Glasgow. The main object of this new establishment will be to collect and tabulate all the available data on creep and rupture properties of high temperature materials. The data for British products will be issued in an agreed form as far as considerations of commercial security will allow. Later, the scheme will be extended to include fatigue and other mechanical properties ; foreign materials ; and information regarding test procedures and testing machines. This centre should prove of service to design teams engaged on high temperature reactor projects - all companies and organizations concerned with the production or use of such materials are invited to participate.

DANES GET NEW EQUIPMENT The University Institute for Theoretical Physics, Copenhagen, has ordered a 10-million-electron volt tandem Van de Graaff accelerator from the High Voltage Engineering Corporation, similar to that installed at Chalk River. It will be used for fundamental investigation of atomic nuclei under the direction of Dr. T. Huus



Widening the field of isotope applications

Two contracts have been issued in the US which should lead to the greatly increased use of radioisotopes. The National Canners Association are undertaking a three-year programme to investigate tracer techniques to detect and measure detergent residues on washed food products and to evaluate commercial food washing practices. The first phase of this work is anticipated to be completed by next April.

Isotopes Inc. are carrying out a six-month study to investigate the industrial potential of applications of radioisotopes in the gas industry. The American Gas Association is providing assistance by way of consultation, evaluations and other services - techniques covering development, production, processing, transmission and storage of industrial gases will be included.

Mainly Discussions

LONDON. At the 5th Annual Conference of Standards Engineers, on June 4, organized by a joint committee of the BSI and the Institution of Production Engineers, the establishment in the UK of a formal association of standards engineers was brought significantly nearer and the existing BSI/IProdE committee, suitably reinforced, is to consider the matter in detail.

LONDON. The Institute of Physics held its Annual General Meeting on July 7, when Sir George Thomson was re-elected President. Nine Fellows, 53 Associates, 29 Graduates, 14 Students and 4 Subscribers were elected. Over the past year, membership has increased by 415.

UPPSALA. The 4th International Conference on Ionization Phenomena in Gases, organized by the Institute of Physics, will be held between August 17 and 21.

WARSAW. A conference on the applications of large radiation sources in industry and especially to industrial chemical processes will be held between September 8 and 12 by the IAEA. A particularly large contingent will be attending from the US.

GENEVA. The European Centre for Nuclear Research will hold the International Conference on High Energy Accelerators and their Instrumentation from September 14 to September 19.

CHICAGO. The 3rd Industrial Nuclear Technology Conference will be held between September 22 and 24. Jointly organized by the United States AEC, Nucleonics and the Armour Research Foundation, it covers the non-power uses of nuclear technology in industry, radiation, processing, tracing, activation analysis, gauging and radiation analysis.

MOSCOW. Convened by the Academy of Sciences of the USSR, the International Computer Conference will commence on September 21.

VIENNA. The International Atomic Energy Agency's 3rd General Conference is scheduled for September 22 until October 9.

Operation Anthrax

Towards the end of June, the largest radioactive source, 150,000 curies of cobalt, ever exported was shipped from London for Melbourne. It was produced at Calder Hall, costing some £70,000, and was contained in two ten-ton lead containers ; it will be used by the Westminster Carpet Co, at Dandenong, near Melbourne, to kill anthrax bacilli in unopened bales of goats' hair imported into Australia. Associated equipment was also made in the UK, among which was three special 23ft long Carter & Viner handling tongs (see 'Progress in Industry,' July 1959) arranged with sectional

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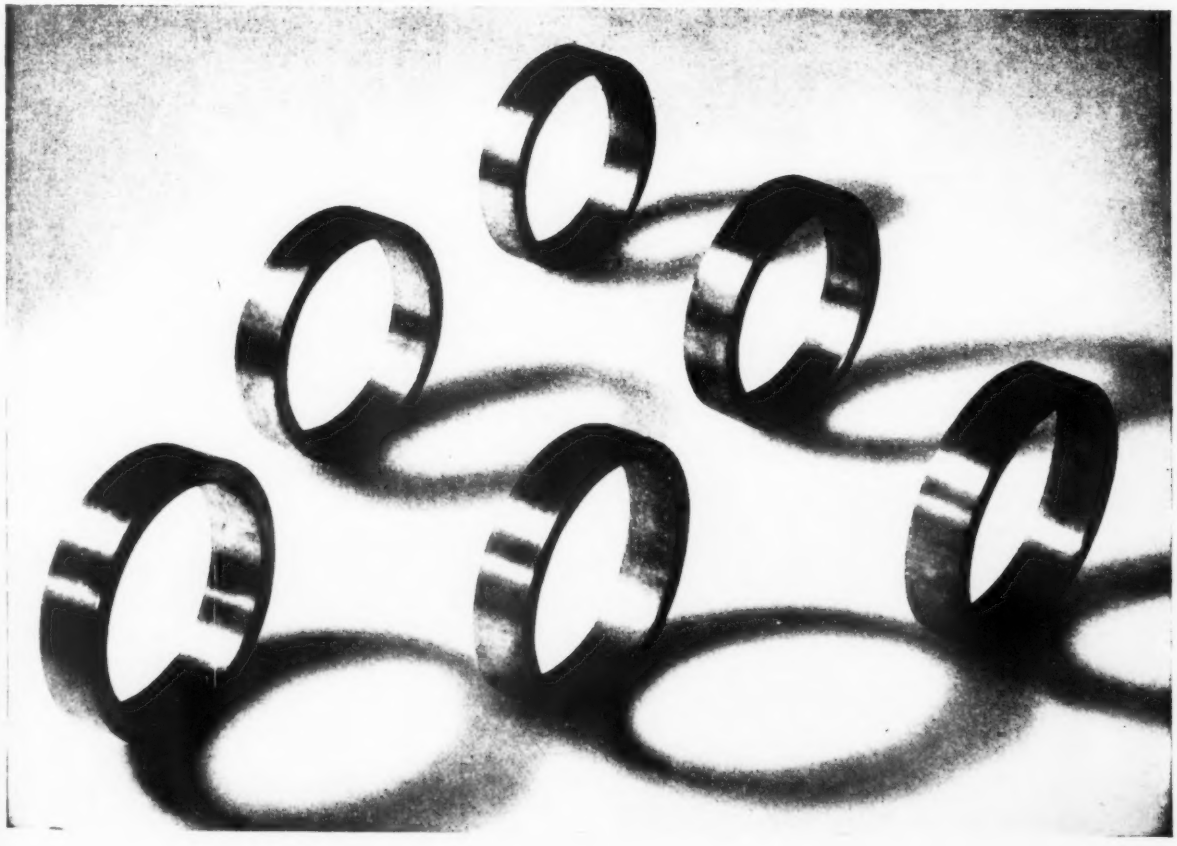

SP 205

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assembly to ease shipment. The overall cost of the installation of this source is estimated to be about £50,000 - the total capital cost is, however, anticipated to be more than offset by not having to open and unravel the bales on their arrival at the docks.

Uranium companies breaking even

Counteracting the general pessimistic outlook regarding uranium mining, news from Canada indicates that favourable results are being obtained by some of the largest Canadian companies. By the end of April, Algom had paid off entirely its funded debt, while Consolidated Denison had repaid a substantial portion of its debt. At the same time, during April, Algom, Consolidated Denison, Pronto and Northspan attained the lowest-ever operating costs with the result that their earnings have increased steadily

AEC woos US petroleum industry

The American Bureau of Mines have received responses from twenty-one major petroleum chemical firms to proposals regarding experiments with underground nuclear explosions in oil-shale deposits. All but two of the companies indicated that such experiments should be carried out and several expressed their willingness to participate and help finance at least part of the project. Encouraged by these reactions, the US Government plans a meeting for further discussion with the petroleum and chemical producers.

In Brief

EARLY ORDERS FOR TRAWSFYNYDD. Nuclear Civil Constructors, the civil engineering branch of Atomic Power Constructions Ltd., have placed their first order for this project. Valued at some £250,000, the contract is for an extensive temporary township to be built by Medway Buildings & Supplies Ltd. and will be located on the main A487 road between Dolgelly and Trawsfynydd.

Another contract, worth £262,000, has been placed with Shell-Mex and BP Ltd. to supply, over the next 4½ years, all the contractor's petroleum products requirements.

MORE CONTRACTS. The UK Atomic Energy Authority have placed contracts with Hawker Siddeley Nuclear Power Co. Ltd. for the designs of a glovebox and vacuum melting furnaces.

EXPANSION JOINTS FOR BERKELEY Going through Ashmore, Benson, Pease and Co's new South Works at Stockton-on-Tees is a batch of 36 bellows joints for the gas duct circuits at Berkeley power station. The actual bellows are by Industrie Werke Karlsruhe but otherwise the units are completely built here to AEI-John Thompson design. Note the second unit from the right in the front row, fitted with temporary end domes for hydraulic testing. ABP and Co. were responsible for the stainless steel fabrication at the original Windscale primary separator and solvent recovery plant. They are now working on extensions to this installation and are currently fabricating a series of special heat exchangers in pure Monel. The new South Works cover nearly 400,000 sq.ft and represent the half-way mark in a 20-year expansion programme. Since this was started in 1949 the company's output has quadrupled while the staff has only doubled

ANTICIPATING INDUSTRIAL APPLICATIONS. Nuclear Materials & Equipment Corp. (NUMEC) has expanded the size of its Apollo plant by 25% since June 1 and a further increase of 18,000 sq ft is expected by next November, when it is anticipated a new laboratory building especially designed for the handling of plutonium will be completed.

RAPID DELIVERY. On June 15, the reactor control instrumentation, completed ahead of schedule by Ekco Electronics, was despatched by air to Copenhagen to be installed in DR3 at Risø.

EUROPEAN TOUR. At the end of June, George Kent's mobile exhibition started a six-month tour of Switzerland, Spain, Yugoslavia and Italy. While in Spain, a large group of instrument mechanics will be given a five-weeks course.

RADIOBIOLOGICAL RESULTS. The first report of the Agricultural Research Council has been issued and covers a survey of the strontium-90 content in human diet in the UK during 1958.

LARGE URANIUM ORE ORDER. Susquehanna-Western Inc. has contracted to purchase from Vitro Minerals Corp. 480,000 lb of concentrate annually, up to the end of 1966 - total purchases are expected to exceed $M15 in value.

MORE US RESEARCH. The AEC put into effect 19 life science research contracts, totalling some $334,000 in value, in May. Six are new and the remaining thirteen contracts are renewals to continue work already in progress. Of the new contracts, one is for work in medicine, one in environmental sciences and four in special training.

AMERICAN FITTINGS IN UK. Thorn Electrical Industries Ltd. announced on July 15 that as a result of an agreement between their subsidiary, Atlas Lighting Ltd., and Luminator Inc. of America, they have acquired a licence to manufacture and distribute Luminator lighting fittings in this country. These products will be handled by the Components and Connector Division of Thorns.

AEC RETRENCHES. It has been decided to dispose of the uranium feed materials processing facilities located at Destrehan Street, St. Louis. These works have been on a standby basis since July 1, 1958, following the start of operations of the new Weldon Spring feed materials production centre earlier in 1958.

REORGANIZING ADVANCED COURSES. In June, Mr. A.A. Part, Head of the Further Education Branch of the Ministry of Education, said that it would not be possible to create colleges comparable with the technical universities on the Continent unless the location of advanced courses are concentrated to ease the scarcity of staff and cost of equipment.

CHANGE IN NAME. From July 1, Besson & Robinson Ltd., makers of electrical relays, change their name to B. & R. Relays Ltd.

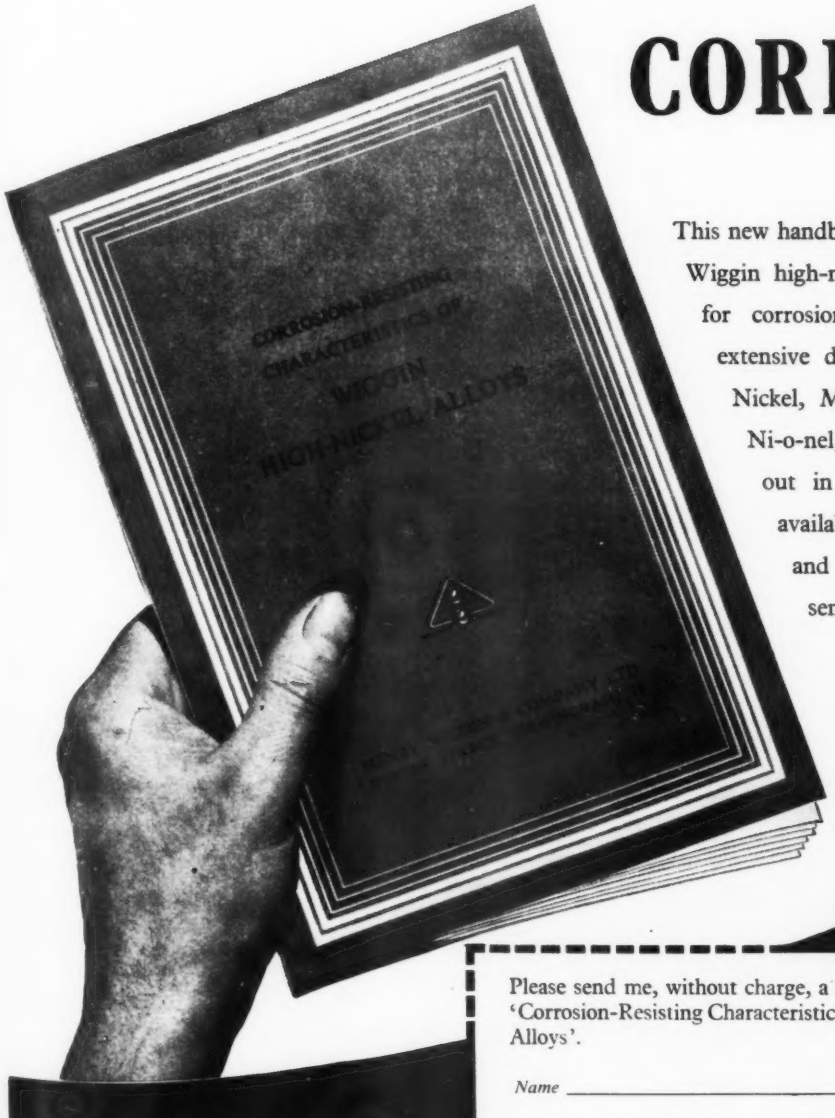
CHEAPER AND BIGGER RESISTORS. Resulting from improved manufacturing techniques, the ohmic range of Jobling Metal Oxide Film Resistors has been extended up to 2 megohms. Due to increased sales, substantial price reductions have been made and these resistors will, in future, be marketed under the registered trade name 'ELECTROSIL'.

125 YEARS OF ENGINEERING. Sulzer Brothers Limited of Winterthur are, this year, celebrating the 125th anniversary of the foundation of the company. The management still includes members of the fifth and sixth generations of the family founded by Salomon Sulzer nearly 200 years ago.

NUCLEAR POWER now has available, for loan to bona fide lecturers, 2 x 2in. slides of the following colour and black and white drawings published in the magazine, Berkeley, Bradwell, Dounreay, Chapelcross, Advanced Gas-cooled Reactor, Hinkley Point, Calder Hall, Enquiries to the Editor.

Knowing where to find the answers on

CORROSION



This new handbook describes in detail the many Wiggin high-nickel alloys specially developed for corrosion-resisting duties. It includes extensive data on the properties of 'AT' Nickel, Monel, Inconel, Corronel B and Ni-o-nel, and gives results of tests carried out in many corrosive media. It is available, without charge, to designers and chemical engineers. May we send you a copy?

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They said...

points from papers, speeches, conferences

Is it costing too much?

The heads of the major engineering organizations continue to emphasis the ever-increasing cost of development and 'keeping up with the Jones's' in the nuclear field. At the annual general meeting, on June 15, Mr. R.B. Potter, chairman of Simon-Carves Limited, was concerned with the spending of 'exceptional sums on research and development with no real assurance of proper continuity of work in the future . . . . The position is no brighter on the export side, as there is no evidence that foreign countries are ready to place orders regularly with this country. Indeed, in Europe there are indications that a number of contracts will go to America, apparently because of the more attractive terms which are being offered both for credit and sale/re-purchase of fuel elements.'

These sentiments were echoed by Mr. Richard Miles on the occasion of the 69th annual general meeting of Head, Wrightson and Co. Ltd., on July 9, when he said 'I see no reason to depart from my warning two years ago, repeated last year, that to pioneer builders of nuclear power stations reasonable profits will rarely accrue. There are now too many Groups chasing too little work. This is not in the national interest at a time when there is a shortage of scientists and technicians'.

From across the Atlantic, in New York, Dr. Chauncey Starr, general manager of Atomics International told the Nuclear Energy Writers' Association, at the end of June, that the 'separation of fact and fantasy is essential to the sound growth of the industry.' In addition he said that incentives for industries involved in atomic energy should be determined, additional experimental and prototype plants constructed and subsidiaries between American and foreign countries to foster commercial interests should be formed. (See last month's 'Worldview' page 67).

Comments by Sir Leslie Gamage, MC, Chairman and Managing Director of The General Electric Co. Ltd., underlined, in his Annual Review and Accounts for 1958-59 on July 18, the difficulties confronting nuclear power station builders. Whether such contracts will be reasonably profitable is difficult to predict and the GEC have come to the conclusion that 'there is only a limited market for the present form of gas-cooled graphite-moderated reactor overseas owing to its high capital cost. An intensive new approach to reactor dimensions and electrical capacity is necessary to reduce capital cost'.

Reflecting the optimism due to Atomic Power Constructions Ltd. having been awarded the contract for the Trawsfynydd power station, Mr. O.J. Philipson, chairman of Richardsons, Westgarth & Co Ltd (one of the member companies of APC), referred at the annual general meeting on July 17, at Wallsend, to the build up of research facilities at Heston. 'Considerable expenditure has been involved, but this, it is considered, has been expenditure which must be met, if a share in the important nuclear power field, for land and marine use, here and overseas, is to be secured'. So far no agreement has appeared to have been reached between the various consortia as to what is considered a reasonable level of expenditure for research and development but at least some cut-back seems inevitable.

Nuclear activities in the Middle East

The future prospects in the atomic energy field were reviewed by Sir John Cockcroft in his address at the opening of the Tehran Nuclear Centre on June 22. While the date at which nuclear power will be competitive with other fuels appears to have receded a little due to the fuel situation of the world temporarily changing and coal and oil being available at lower prices, in the long run 'it seems to be quite obvious that nuclear power is essential if the living standards of mankind are to be steadily improved'. Already atomic energy is being used in the Middle East to improve conditions and for industrial purposes - the 'Baghdad Pact Nuclear Centre was able to help in the foundation of a Radioisotope Clinic in the Baghdad Hospital and it is now helping the University of Shiraz to install a 1000 curie radio caesium source for the treatment of cancer.' In conjunction with Harwell, radioactive gauges have been used in Kuwait to show how the level of the interface between brine and oil in a bore hole can be determined and a student from Iraq has developed a radioisotope method for measuring impurities such as sulphur and lead in oils. In these ways and with assistance from the American and British authorities, the Nuclear Centre at Tehran will carry out research work on specific problems of the area.

NAMES IN THE NEWS

Dr. D.H. PRINGLE has been made chief physicist of Nuclear Enterprises (GB) Ltd.

Mr. J.F. PERRY has been named deputy chairman of Eutectic Welding Alloys. For many years Mr. Perry was with Metropolitan-Vickers Export rising to the post of managing director.

Mr. J.F. MacGILLIVRAY has taken up a post as chief staff officer with the Atomic Energy Authority. He will be based at Chapelcross.

Dr. C.M. CAWLEY has been appointed chief scientist to the Ministry of Power on the retirement of Sir KELVIN SPENCER.

Mr. S. BLACK has left British Aluminium to work at APV as senior sales engineer.

Mr. W.C. MOORE was recently appointed project manager for General Atomic's maritime gas-cooled reactor project.

Mr. A.L.G. LINDLEY has been appointed vice-chairman and a managing director of The General Electric Co. Mr. Lindley has been with the firm since 1918 and is responsible for General Electric's atomic energy activities.

Mr. R. YEOMAN has joined the board of James Hodgkinson (Salford) Ltd.

Mr. R.H. FOSTER has been appointed a managing director of M. & W. Grazebrook Ltd.

Mr. R.J. SMITH, chief projects engineer of GEC's atomic energy division arrived in Japan last month where he will be in charge of the organization supervising the erection of Japan's first atomic power station.

TOKAI-MURA

At Tokai-Mura, 70 miles north-east of Tokyo, The General Electric Company Limited of England is to build Japan's first nuclear power station. This 150 MW station will be powered by a single gas-cooled graphite-moderated reactor of the same basic type as the two which are being built by G.E.C. at Hunterston in Scotland. In producing a design to ensure the safety of the installation even under severe earthquake conditions, G.E.C. and her associate Simon-Carves Ltd., have brought to bear the results of much experimental work. For example, models of the pressure vessel mounted on a supporting skirt were subjected to horizontal loads such as would arise from earthquake shock.

Unique protective devices will be provided capable of effective operation even if the core should be severely damaged and tilted to an angle of 45°. In addition to the normal control rod system there is a unique arrangement of boron steel balls which would be released into the channels in the core by seismic pick-ups outside the station or by displacement of the pressure vessel, the core itself, the grid or various other critical parts of the reactor. The station is expected to be in full operation in 1963.

G.E.C. OF ENGLAND

ATOMIC ENERGY DIVISION

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND, ERITH, KENT

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Book Reviews

The best so far

MATERIALS FOR NUCLEAR REACTORS Bernard Kopelman McGraw-Hill 1959 : 320 pp 93s

The materials field in nuclear energy is a most difficult subject to cover, due partly to its diversity and partly to the speed with which the subject matter advances, so that a would-be author finds that Chapter I is obsolete before Chapter 15 is safely on paper. Furthermore, most of the books written have enormous gaps, due presumably to the authors' acquaintance only with limited aspects of the subject.

Of the books that have appeared, so far this is certainly the best. It is readable, a very convenient length, up to date (for example it contains a fair amount that is new to the writer), and covers all branches of the subject. It is, for example, one of the few American text books to acknowledge the existence of magnesium as a canning material.

The work is the product of thirty specialists. Mr. Kopelman is to be congratulated, both upon his choice of writer and on the skilful way he has edited the book, so that its diversity of authorship does not produce irritating conflicts of style and presentation. The reader is taken smoothly through the life cycle of uranium from ore to the chemical processing of spent fuel elements. On the way he is introduced to the properties of reactor materials, and in particular radiation effects are dealt with in a very systematic and thorough way.

L.M. Wyatt

Postgraduate value

THE STRUCTURE OF METALS 1959 London : Institution of Metallurgists 118 pp Price 25s.

This collection of four lectures was given at the Institution of Metallurgists' annual refresher course in 1958 and is devoted to a survey of recent advances in metal physics. The subject matter reflects the rapid progress in the theory of the electron structure of metals and the dislocation theory of plastic deformation made during the last two or three decades.

In the opening lecture Professor G.B. Raynor discusses the physical properties which distinguish metals from other classes of solids and traces the development of electron theory from the early ideas of Drude & Lorentz to the most recent concepts of quantum theory. It is unfortunate that the emphasis is mainly on the band theory whilst Pauling's chemical approach, which is certainly at present the most useful way for metallurgists to discuss cohesion, is dismissed in half a paragraph. Dr. J.A. **Catterall**'s lecture describes the ways in which properties of electrons at the Fermi surface are determined from measurements of electronic specific heat, magnetic susceptibility and electrical effects, and how information about density of states curves is obtained from soft X-ray emission spectra.

The remaining two lectures by Professor A.G. **Quarrell** and Dr. J. Nutting deal with the dislocation theory of plastic deformation and its recent brilliant verification by the direct observation of dislocations in the electron microscope and by other methods. The reader is left wondering whether the lectures are not more suitable for the advanced or first year research student in metal physics than the average practising metallurgist. For such a purpose the book is good value.

A.A. Johnson

For serious writers

THE TECHNICAL WRITER J.W. Godfrey and G. Parr 340 pp London 1958 : Chapman & Hall Price 45s

Very few indeed are born with genuine literary gifts but good straight-forward descriptive writing can certainly be acquired. It takes a little application of course, but for an engineer or scientist it is an accomplishment well worth working for. Most technologists have at some time or other to do some writing, even if it is only the preparation of the occasional private report and if this is not done in a manner which quickly communicates the ideas to those for whom they are designed, the value of the original work can in many cases be completely obscured.

Described, accurately, as 'an aid to the presentation and production of technical literature,' this book is however slightly mistitled. The authors say they have not set out to write a book on the art of writing but have rather concentrated on the processes that separate the manuscript from the finished article. For this reason they have assumed that the would-be writer is grounded in the principles of composition and set out only to show him how to avoid common pitfalls and put a final polish on his work.

Well written and informative, *The Technical Writer* can be recommended to anyone who takes his writing seriously.

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Conventional oils cannot live in conditions of atomic radiation. Such conditions are inseparable from certain parts of any mechanism designed to produce power from nuclear fission. This, and other allied lubrication problems, was the challenge which faced oil technologists everywhere. And, as so often in the past, Wakefield-Dick's research team produced the answer. An entirely new series of oils and greases, resistant to radiation and named "Nucleol", is now available to lubricate the wheels of this Atomic Age.

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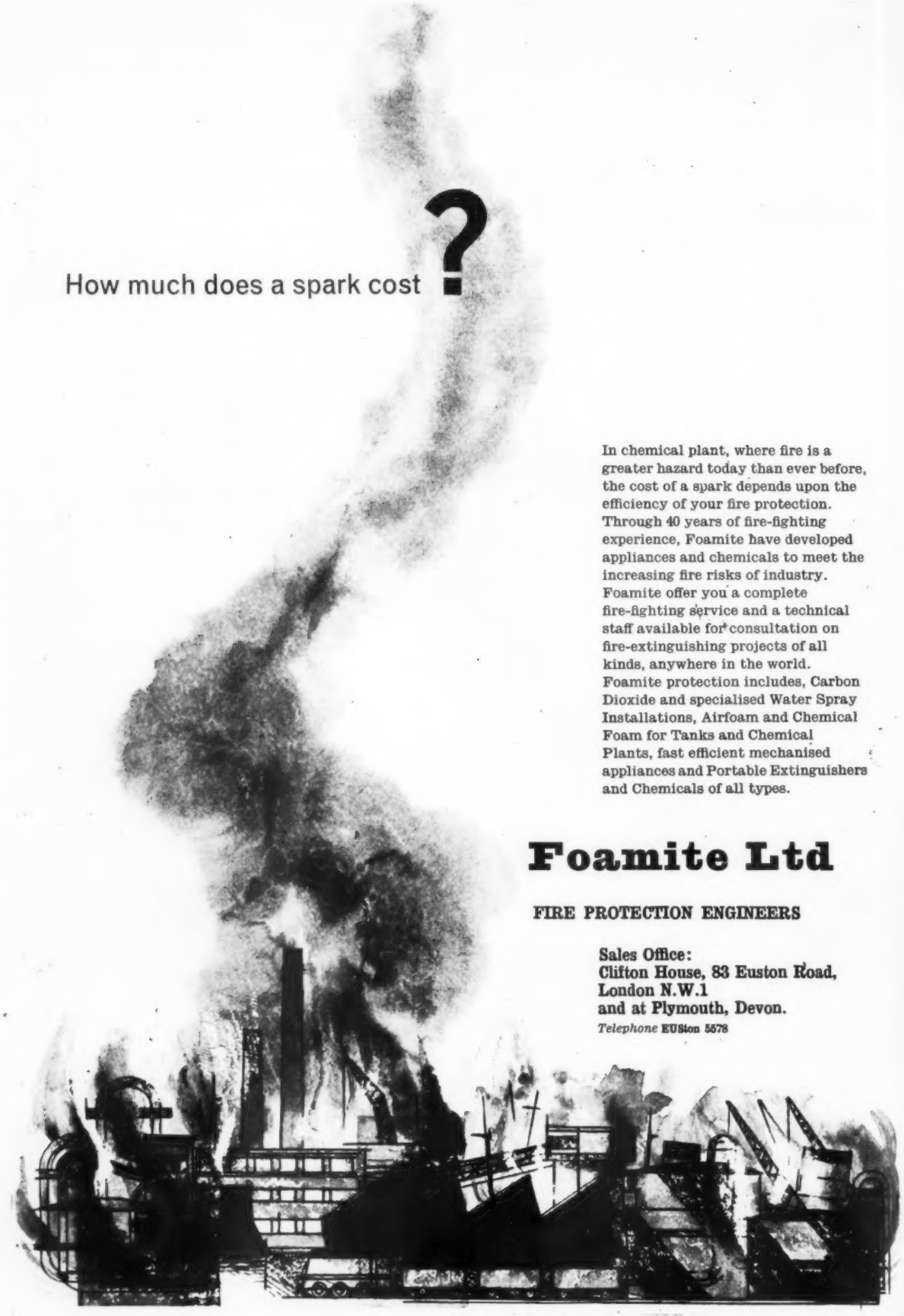

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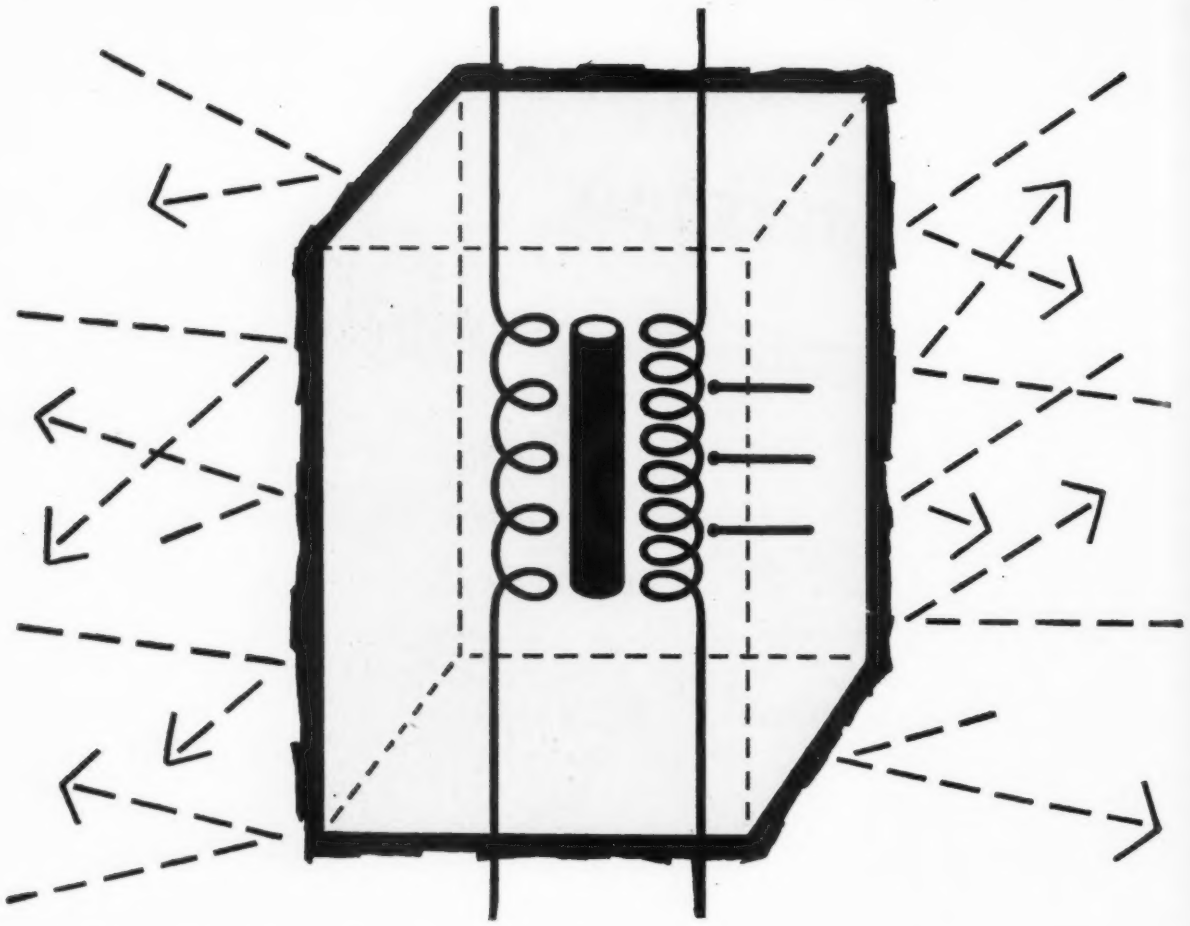

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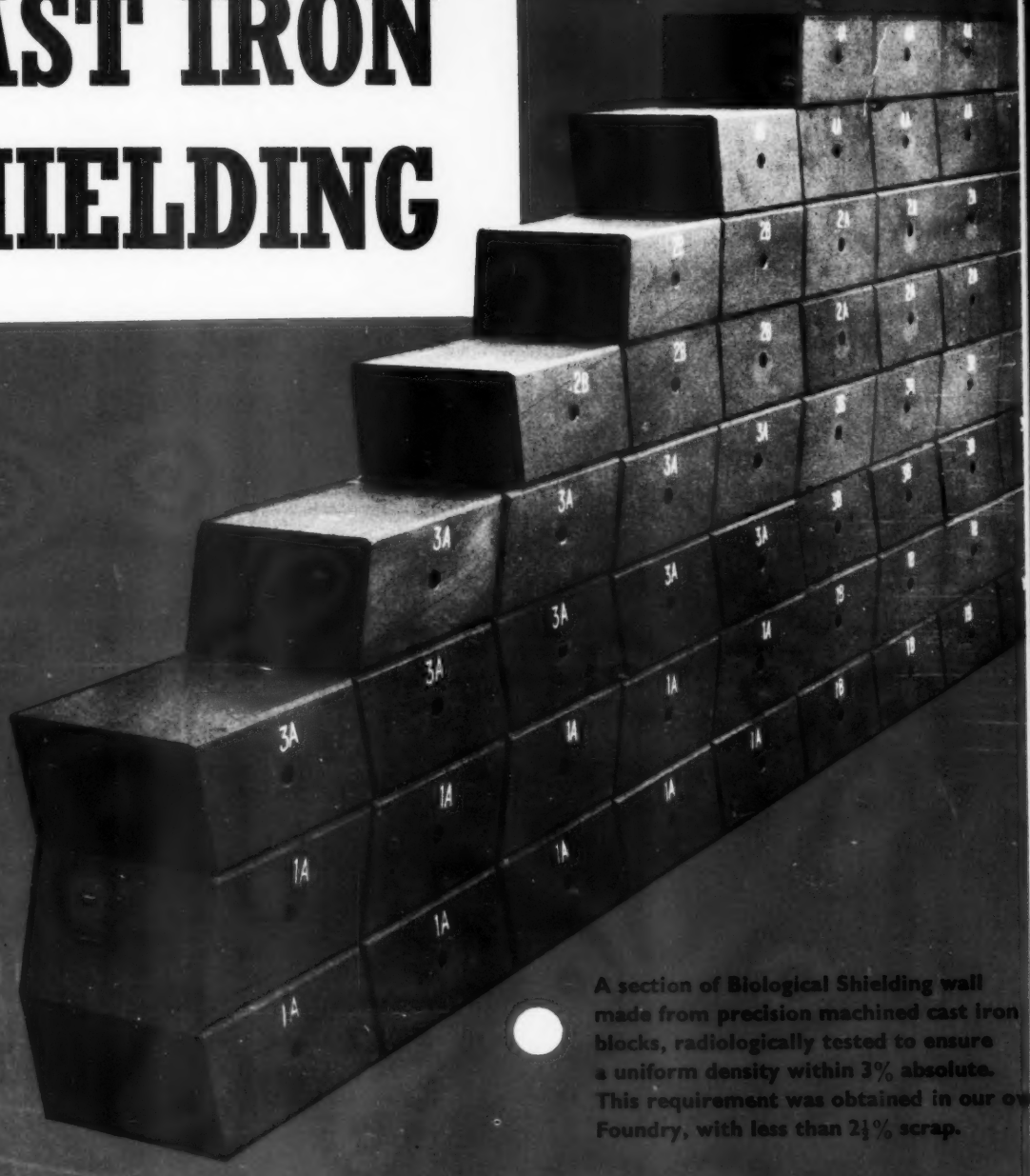

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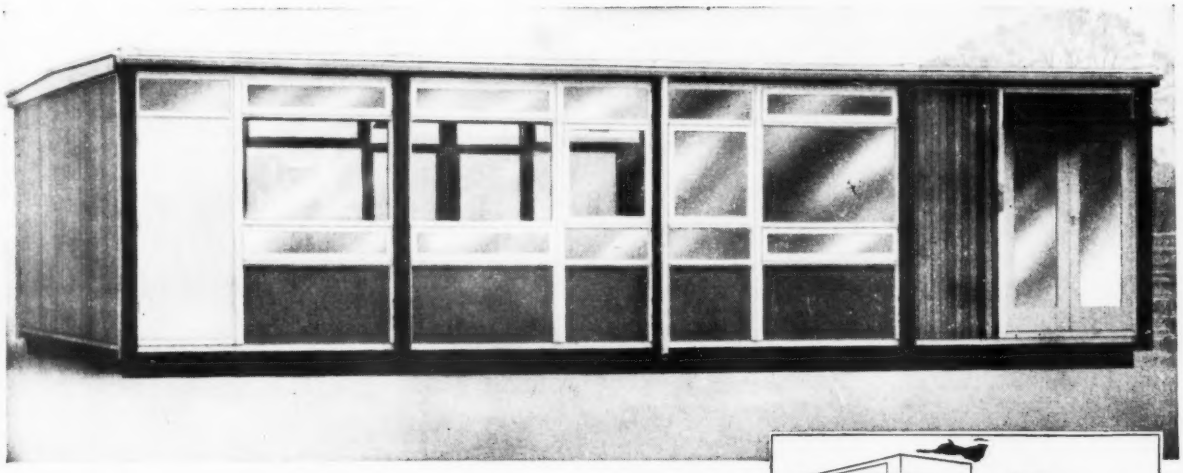

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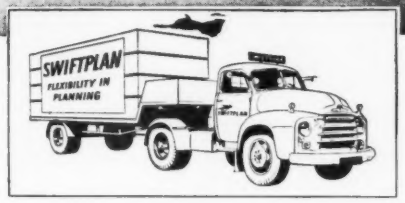

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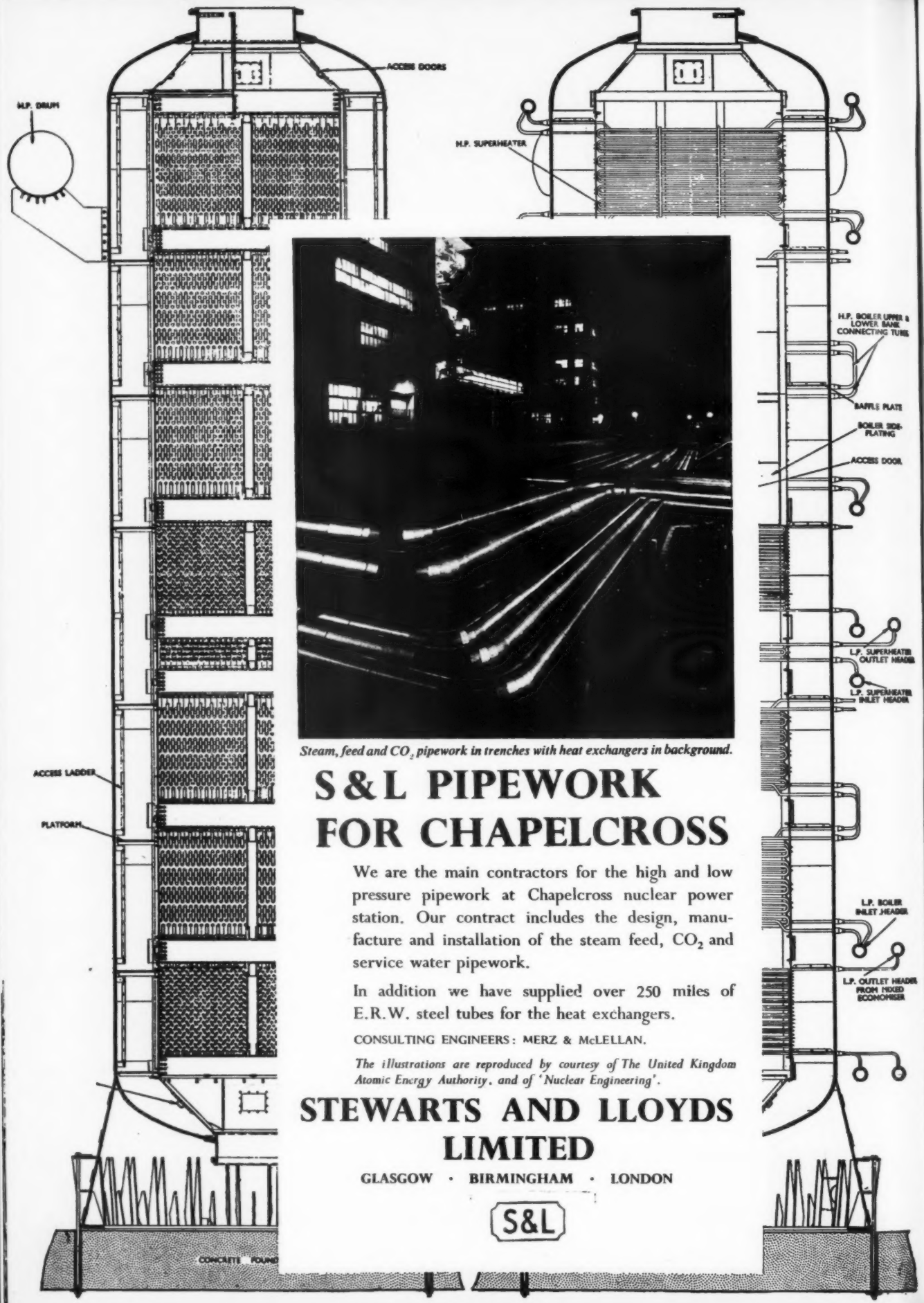

Steam, feed and CO_2 pipework in trenches with heat exchangers in background.

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L'ÉNERGIE ATOMIQUE

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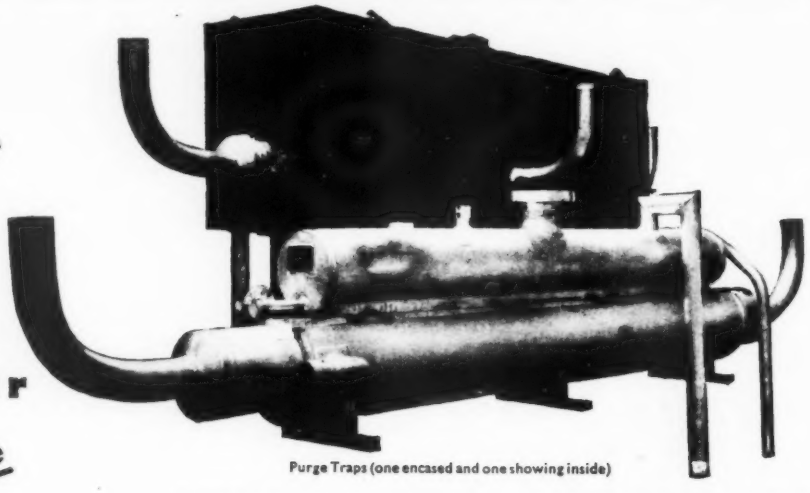

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A vast and ever increasing range of products for the Nuclear Industries is flowing from our factories. We manufacture everything from large fabrications down to the finest tube. All our products are made and tested by the most advanced scientific and technological methods—Argon Arc welding, X-raying, crack-detection, pickling and vacuum-testing. Your enquiries regarding fabrications in stainless, stainless clad, monel, copper and other non-ferrous and ferrous metals, will meet with our immediate attention.

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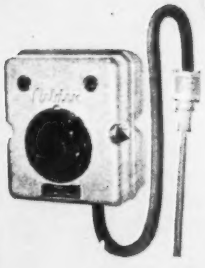
Temperature Measurements

INDICATING **within 0·25% accuracy**

Thermocouple Amplifier and 6″ diameter indicator. Overall accuracy ±0·25%. Temperatures up to 1600°C. Temperature measuring head and amplifier, also amplifier and indicating meter can be thousands of yards apart (input 0-50 ohms, output up to 4,000 ohms).
Amplifier can be used with Recorder or Recorder/Indicator/Controller.
Multipoint instrument (illustrated) gives very low cost per point and automatic correction for varying cable lengths to measuring points.
Write for publications CAP. 1, 200 and price lists.

RECORDING **single & 4 point**

Resistance Thermometer, single and 4-point recording.
Chart diameter 11″, various speeds. Accuracy ±0·5%.
Covers temperature spans down to only 15°C between —200° and +500°C.
Platinum measuring head and recorder can be up to 250 yards apart.
Indicating and/or electrical or pneumatic Control facilities available.
Other recorders for temperature up to 1600°C.
Write for publications 209,200, CAP. 1. and price lists.



CONTROLLING **to within 0·1° C**

Precision Temperature Controller.
Differential 0·1% (0·1°C. on range spans of less than 100°C).
Covers temperature spans down to 10°C or 20°F (e.g. 80° to 100°F) between — 200° and +500°C.
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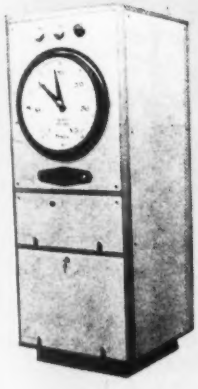
Write for publication 219 and price lists.



SCANNING **up to 140 points**

We supply scanners which will automatically check the temperatures at up to 140 points over a period of 5 or 15 mins. If any point is outside its set temperature limits an alarm bell or light will come on and scanning will cease, alternatively, 'memory' lamps or drop indicators show which points were out of tolerance when last checked. Tolerance bands as close as ±0·25°C can be provided at basic temperatures between —200°C and 1600°C. Provision can be made for differing temperatures and tolerances at each point.
We shall be pleased to quote against your specific requirements. Write for scanning leaflets for fuller information.

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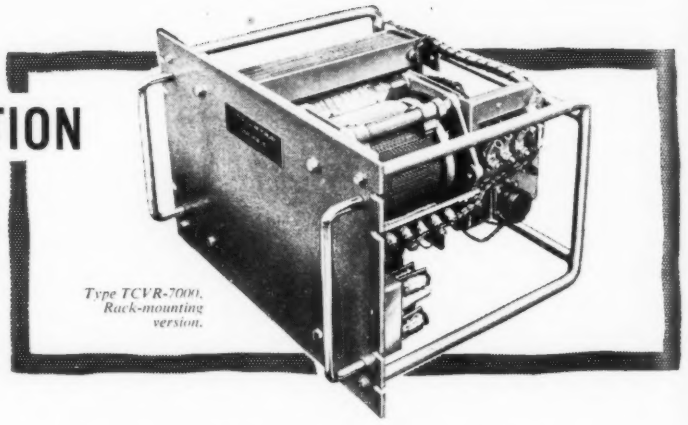
40 VOLTS/SEC AUTOMATIC CORRECTION

—with the type TCVR voltage regulator

The TCVR is a servomechanical automatic voltage regulator having the very high speed of correction of FORTY VOLTS PER SECOND. It provides an *undistorted* output, maintained constant within very close limits (normally ±0.5%) from no-load to full-load, for wide variations in frequency and power factor.

A wide range of models from 1.6 to 12 kVA single-phase, and 4.8 to 36 kVA three-phase, is available, to standard or tropical specification, in cabinets or for rack-mounting. Models are also available in which the output voltage is continuously adjustable over a wide range by means of a panel control. Regulators can be supplied to Services' specification, and special models can be designed to order.

For high-speed, accurate stabilisation *without distortion*—**specify TCVR.**



Type TCVR-7000, Rack-mounting version.

Other products of Claude Lyons Ltd. Stabiliser Division

BMVR: Motor-driven laboratory and industrial regulators ranging from 1·6 to 29 kVA single-phase, and 4·8 to 87 kVA three-phase. Constancy of output normally ± 0·5% from no-load to full-load. No distortion. Speed of correction 1 Volt/Sec. A great variety of models, standard, tropical and militarised, for all applications.

BAVR: Electronic stabilisers of very high accuracy, and very rapid response, with no moving parts. Input range : − 10% to + 5%; output constancy ± 0.15%. Three sizes : 200, 500 & 1000 VA. Exceptionally useful for control of chemical processes, heating, lighting, etc.

ASR: Automatic step regulators, small, inexpensive, and with sinusoidal output waveform. Two sizes : 1·15 kVA and 2·3 kVA. Input range − 10% to + 5%; output constancy, ± 2½%.

ATC: Automatic Tap-Changing Transformers — a development of ASR. Two sizes : 575 VA and 1150 VA. Input range − 20% to + 10% : output constancy, ± 5%. Provide adequate stabilisation for many types of apparatus, at low cost. Also useful as pre-regulators, e.g. in conjunction with BAVR.

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CL/47/E2B

Vacuum Leak Testing Technique for...

OIL DRUMS... HIGH PRESSURE BOILERS... SEALED INSTRUMENTS... LIQUID GAS VESSELS... MERCURY ARC RECTIFIERS... HEAT EXCHANGER ELEMENTS.

A correctly designed pumping system is of vital importance for vacuum leak detection work enabling maximum use to be made of the intrinsic sensitivity of any detector gauge. "Speedivac" leak test pumping units, available in a range of sizes, include such special features as:—

1. Series pumping system with primary diffusion pump backed by a smaller model, backed in turn by a rotary pump.
2. Detector gauge heads situated between the diffusion pumps where the heads are protected from detector gas regeneration from rotary pump oil.
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4. LT6 hydrogen/Pirani and LT4 hydrogen/Palladium detector gauges with sensitivities of 10^{-2} lusecs and 10^{-5} lusecs respectively available if required.

Illustrated is a "Speedivac" 9T01 pumping system which is equipped with a 9" bore oil diffusion pump.

EDWARDS HIGH VACUUM LTD., MANOR ROYAL, CRAWLEY, SUSSEX, ENGLAND. Crawley 1500

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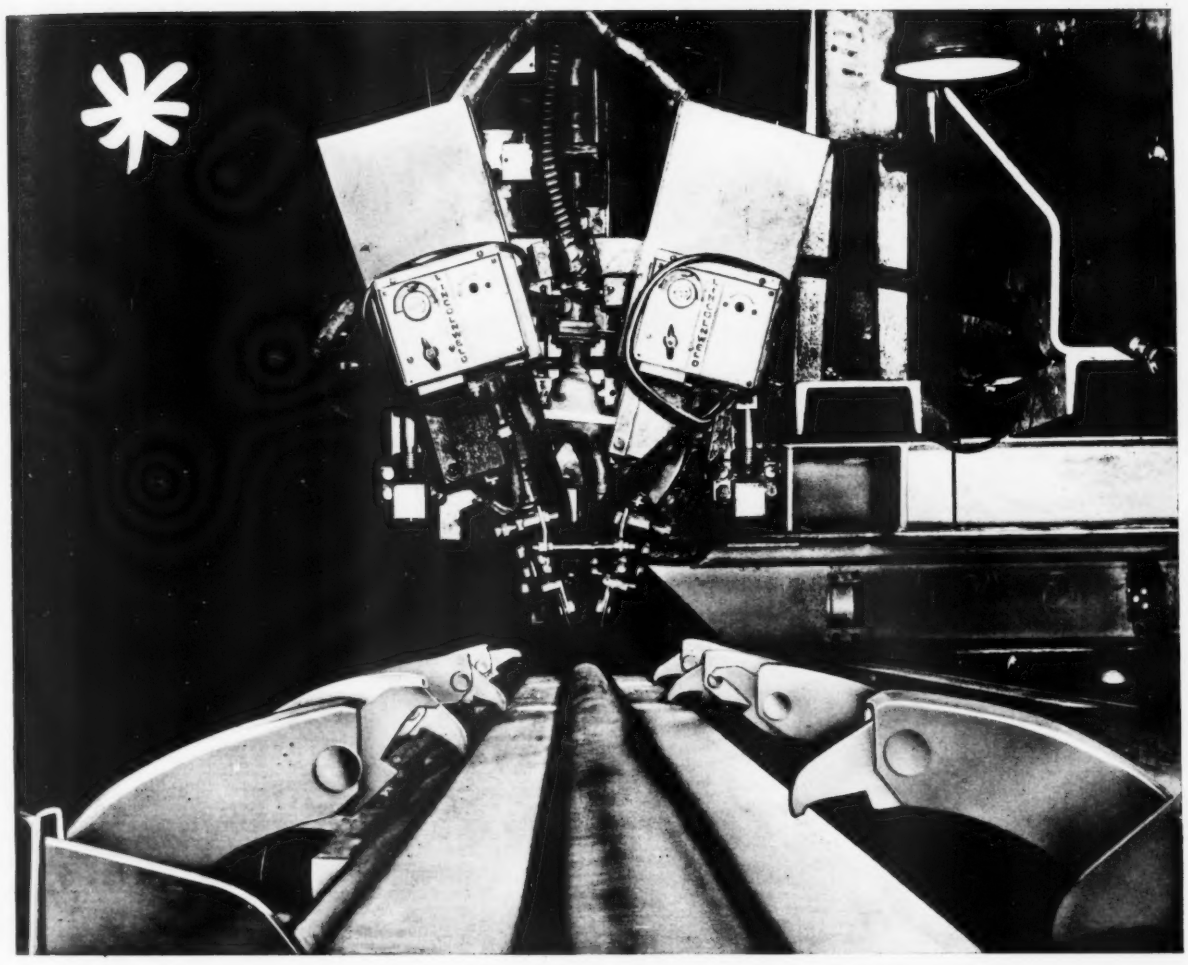

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Our activities in the field of nuclear heat exchange is a natural outcome of this experience.

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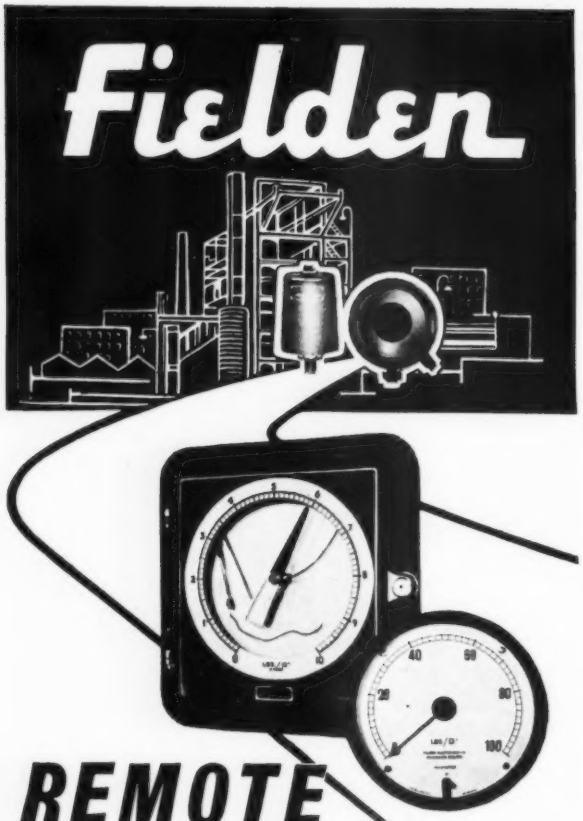

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FOR . . .

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Indicating, recording or controlling or any combination of these features.

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WITH . . .

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Intrinsic safety certificate.

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Indicating Recording Control

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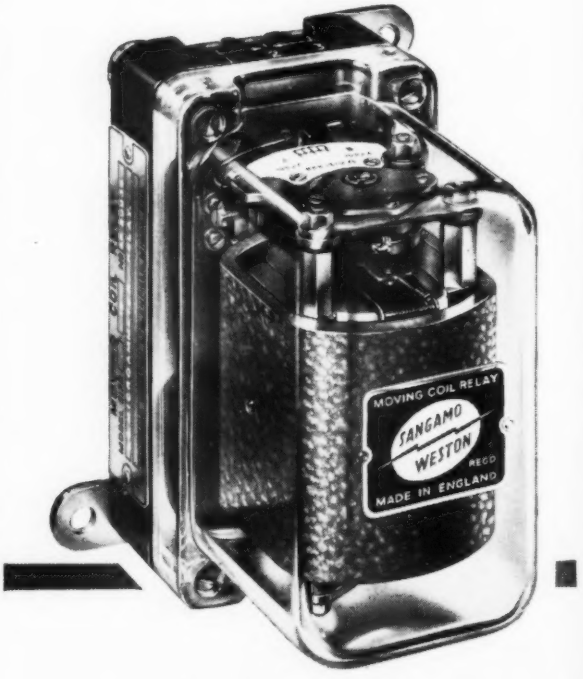
WESTON

MOVING COIL

RELAYS

The simplicity and reliability of relay control for a wide variety of applications has led to the ever increasing use of Weston Moving Coil Relays. Let us have a note of your relay problems and we will be pleased to advise on the most suitable model for any set of conditions. Enquiries should, if possible, be accompanied by full particulars of both control and local circuits.



Illustrated is the Model S170. Other types include the Model S124, a magnetic contact relay which operates with a minimum power input of 0.004 microwatt and the Model S115, a miniature relay, which functions as an "on-off" switching relay.

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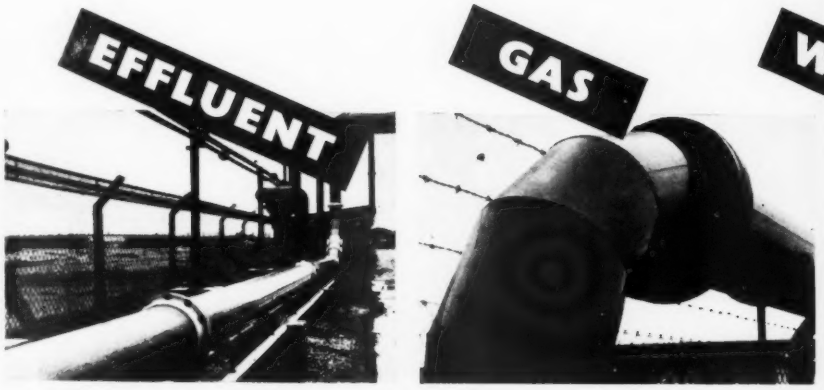

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They apply their knowledge and skill to the problems of achieving the maximum payload possible, capacity, weight distribution, types of lining, insulation, loading and discharging techniques. The result? The finest tank that man can conceive.

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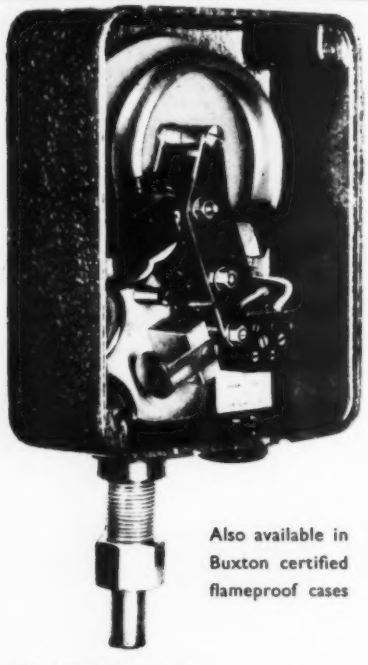

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Il est souvent difficile au client publicitaire d'indiquer dans un espace restreint tous les détails de ses produits. Dans le cas où vous désireriez de plus amples renseignements à ce sujet, veuillez pointer le numéro approprié sur la carte ci-contre et envoyer cette dernière à NUCLEAR POWER.

AUSKUNFTSDIENST FÜR LESER

Es ist oft schwierig für Inserenten alle technischen Einzelheiten über ihre Produkte in einem begrenzten Platz zu bringen. Sollten Sie noch weitere Auskünfte wünschen, streichen Sie einfach die bestimmten Nummern auf der nebenstehenden Karte an, und senden Sie sie an NUCLEAR POWER.

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E' talvolta difficile all'inserzionista di indicare in uno spazio ristretto tutti i particolari dei suoi prodotti. Qualora desiderasse ricevere più ampie informazioni a questo riguardo, favorite segnare il numero appropriato sul cartellino qui accanto ed inviare quest'ultimo a NUCLEAR POWER.

SERVICIO DE INFORMACIÓN PARA EL LECTOR

Se hace a menudo difícil para los anunciantes dar en un espacio limitado todos los detalles técnicos sobre sus productos. Si desea ulterior información, marque los números apropiados en la tarjeta opuesta y mándela a NUCLEAR POWER.

Информация для читателей

Часто бывает трудно рекламирующим лицам давать все технические подробности своей продукции в рекламе. Если Вам понадобятся добавочные сведения, то просто отметьте соответствующие номера на карточке на противоположной стороне и отправьте в NUCLEAR POWER.

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在廣告上以有限的地方來說明一些專門技術，及它們的功能，的確是有受限制的困難。若讀者欲要知道一些詳細的情形就請將對自的表格，取一張下來，將問下有疑問的項目，用筆勾一下寄給子能工程急即可。

読者サービス

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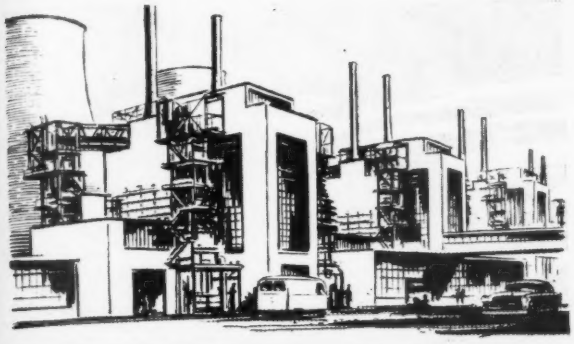

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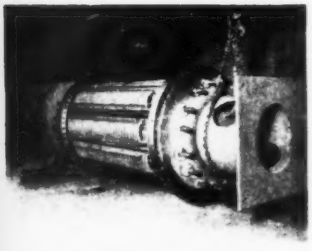

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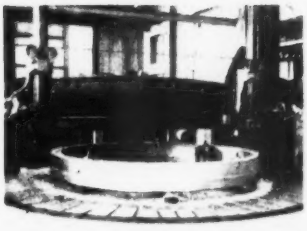

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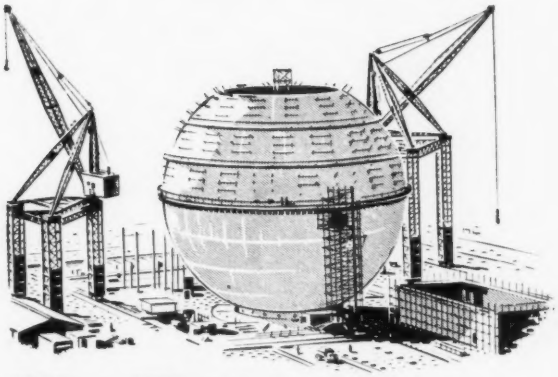
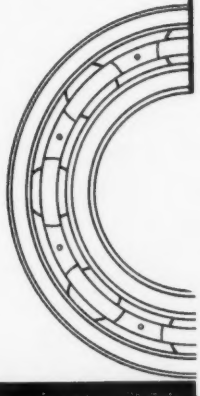


Hoffmann hits the high spots . . .

There they are high up in Scotland at Dounreay on these Derrick Cranes easing the problem of building the great Nuclear Energy Sphere.

Butters Bros. Ltd., of Glasgow have been using Hoffmann Bearings in great variety for their cranes over 40 years, involving ball journals, roller journals, self-aligning ball and roller journals, single and double thrust bearings as well as large steel balls.

Long life, complete reliability and negligible upkeep costs are the secret of their confidence in Hoffmann products.



HOFFMANN

BALL AND ROLLER BEARINGS

THE HOFFMANN MANUFACTURING CO LTD CHELMSFORD ESSEX

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The Unit Superheater and Pipe Co. Ltd., following initial contracts for reactor charge tubes for Calder Hall and Chapelcross power stations, has been entrusted by Whessoe Limited, member company of the Nuclear Power Plant Co., to produce the charge/discharge and control rod stand tubes for Bradwell Power Station.

WELDING CHARGE TUBES

The photograph shows an operator welding one of the 448 charge tubes, using low hydrogen electrodes throughout.

THE **UNIT** SUPERHEATER AND PIPE CO. LTD · UNIT WORKS
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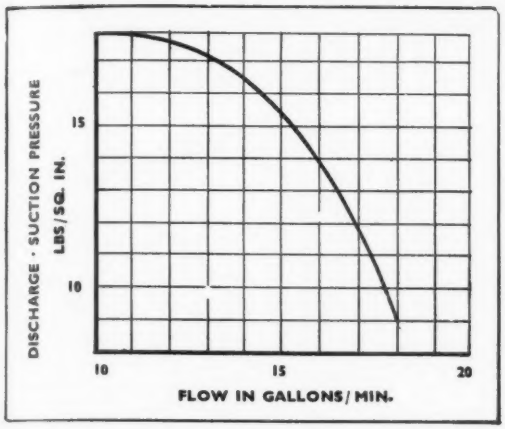

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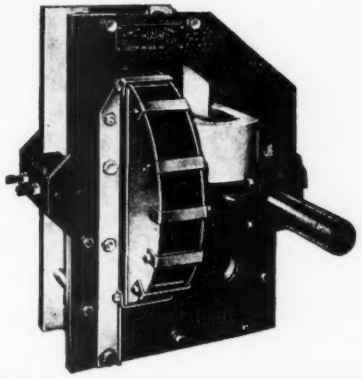
This flat linear induction pump is suitable for almost any liquid metal or slurry compatible with the 18/8/1 stainless steel pump duct. Some early models have been operating since their introduction in 1953 . . . without overhaul . . .

The flexible pumping rate is controlled by a Variac transformer. Nominal bore is 1". Liquid metals up to 400 C can be handled; with fan cooling this can rise to 600 C. The pump end fitting can be supplied to specification, with flexible mounting and expansion couplings.



PROOF OF PALATINE PRECISION . . . 3

This performance curve shows the pump operating with sodium potassium at 350 C., a circuit pressure of 30 p.s.i. and running at 210 volts.

This pump is representative of a wide range of Palatine instruments; many more are produced and developed as prototypes for Britain's largest engineering companies. Perhaps this skill could be of use to you . . .

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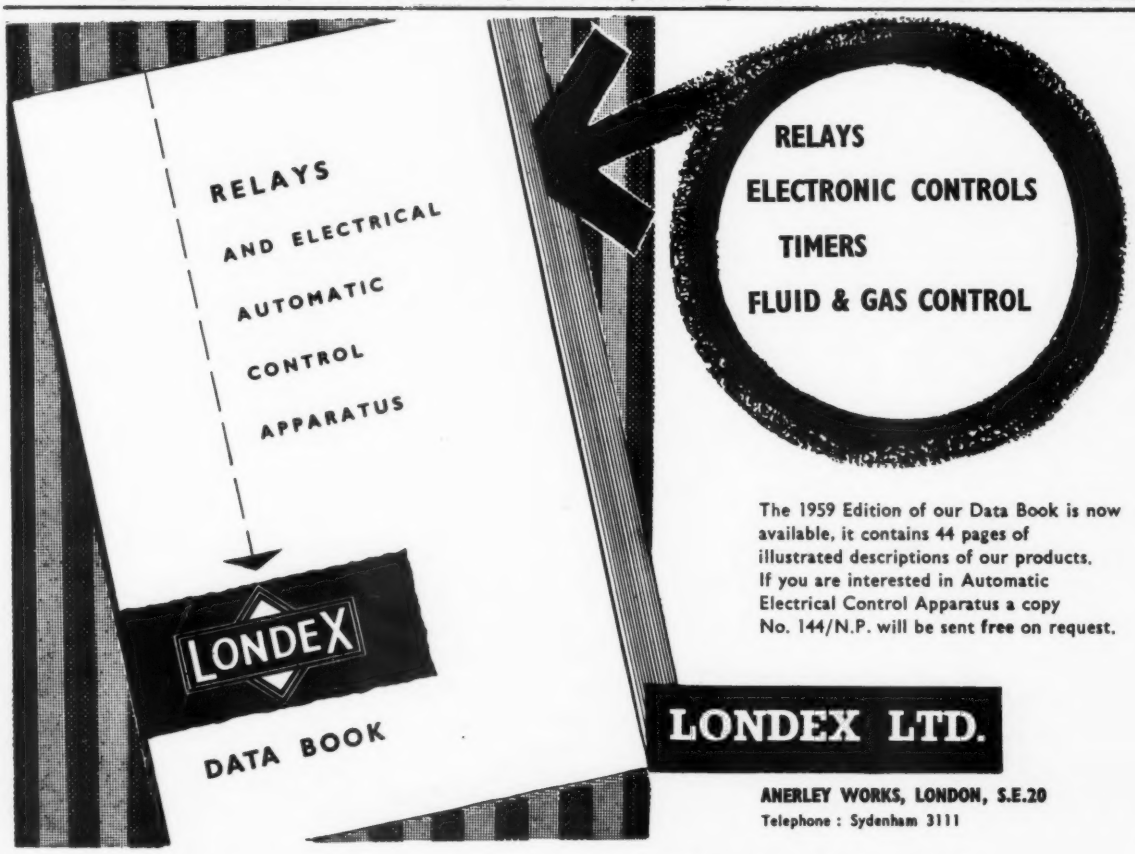

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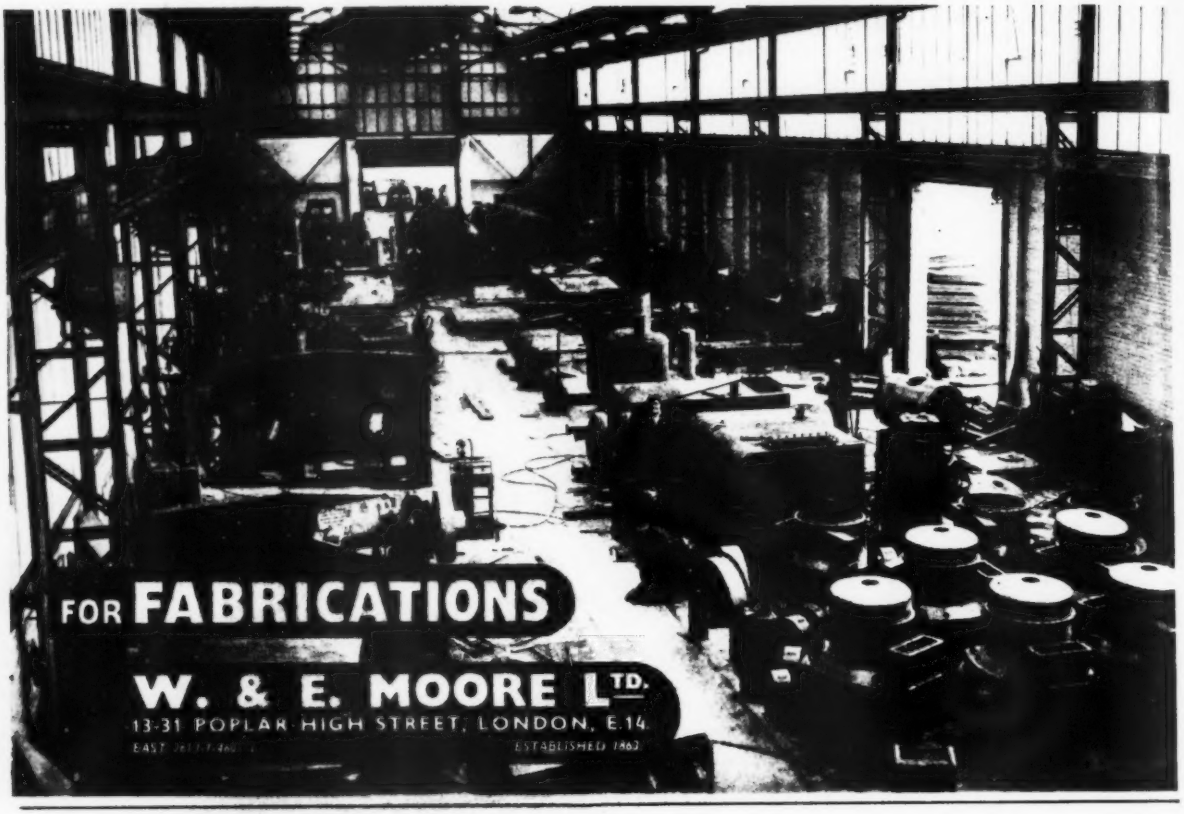

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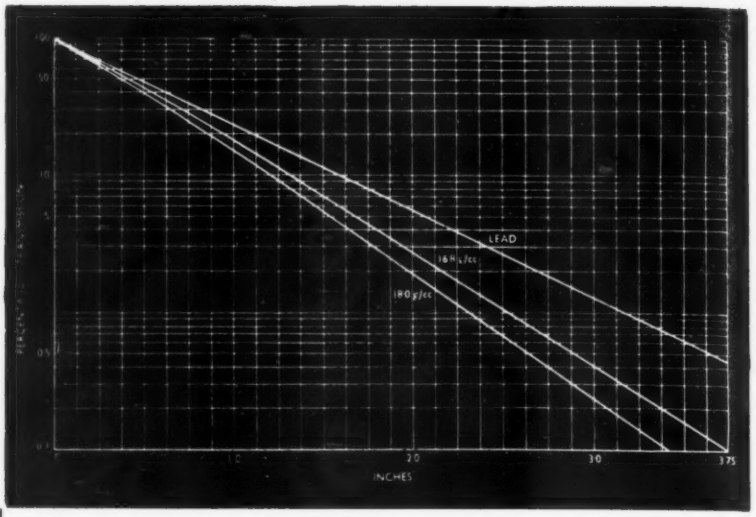
G.E.C.

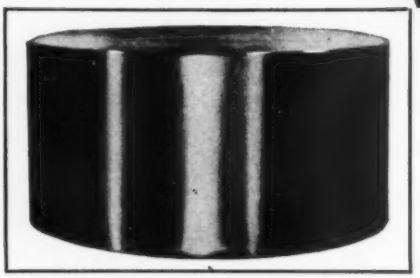
HEAVY ALLOY

supplied in densities
16.8,17.0,17.5,18.0g/cc(nominal)

- ***for screening purposes***
- ***for balance weights***



Broad beam absorption of Gamma-radiation from COBALT-60. Density: 16·8 g/cc. and 18·0 g/cc.



The above piece of G.E.C. Heavy Alloy was made for the United Kingdom Atomic Energy Authority. It weighs 660 lb.

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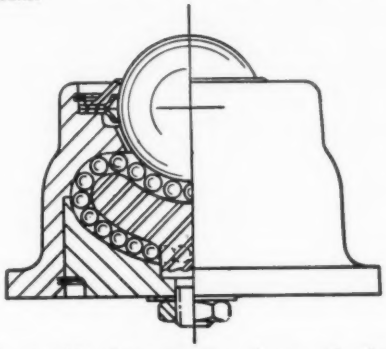

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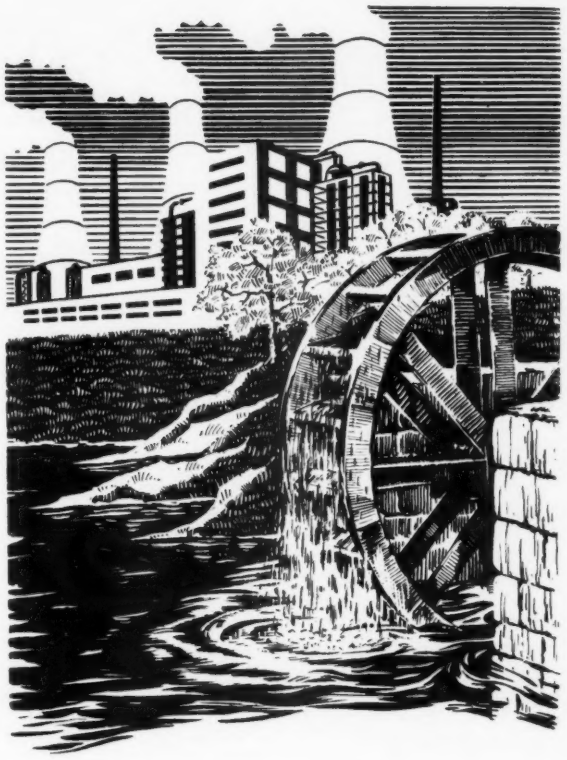

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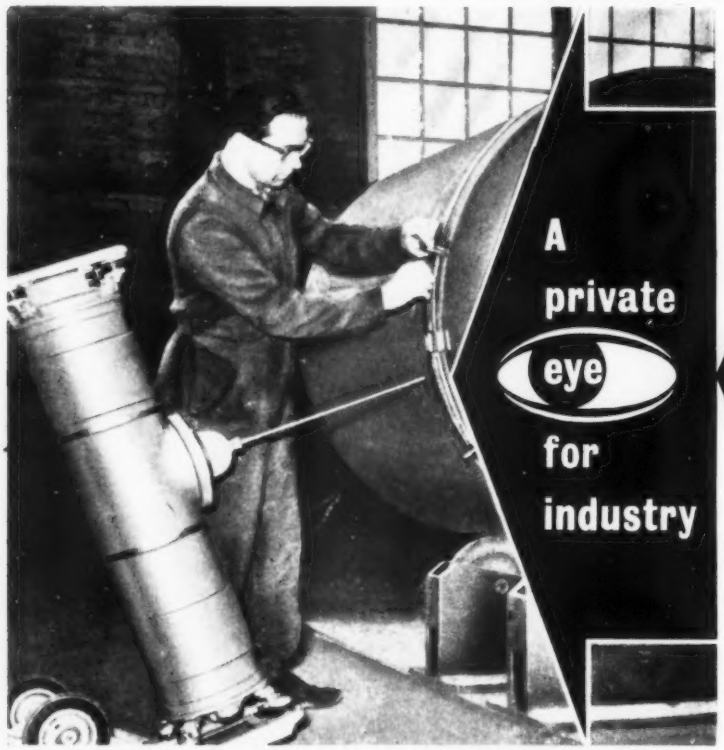

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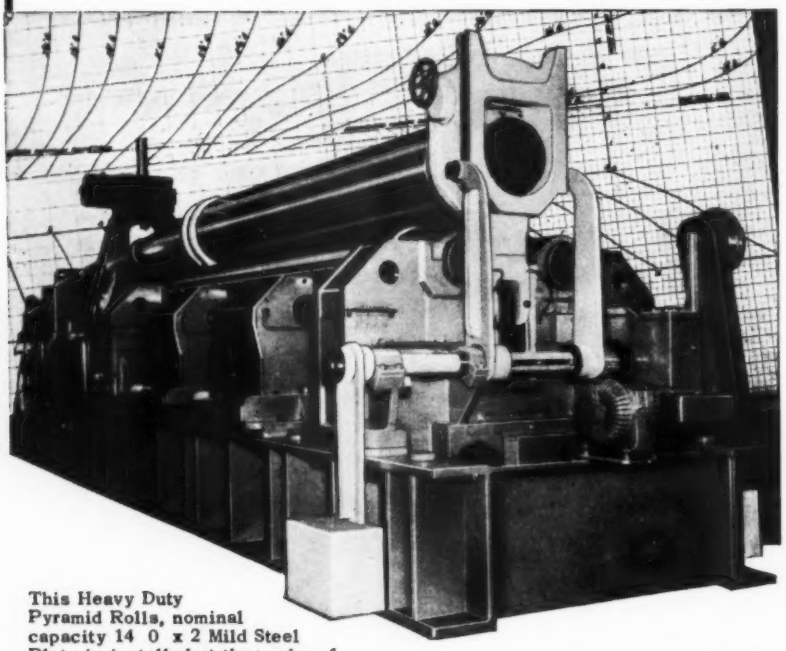

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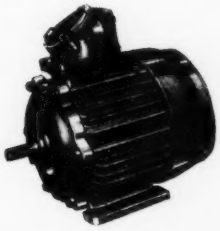

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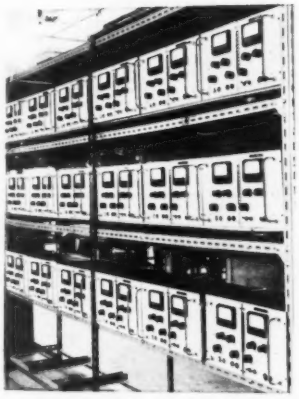

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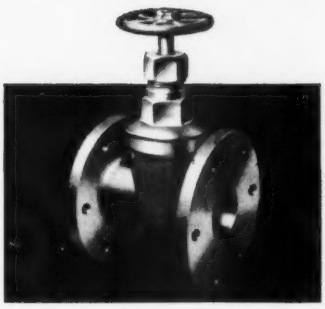

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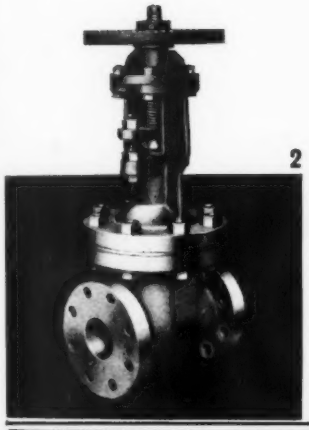

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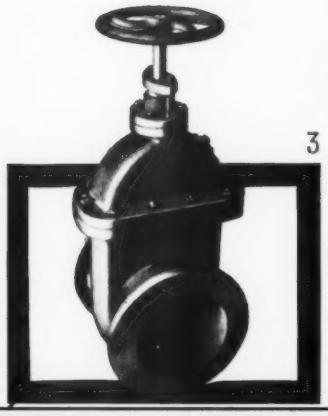

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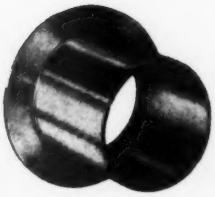

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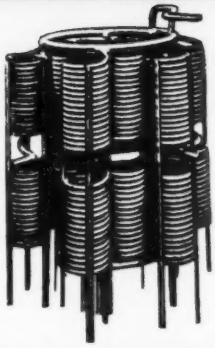

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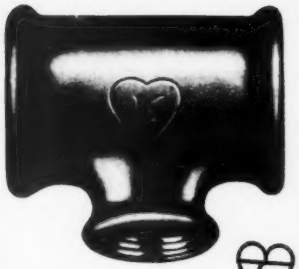

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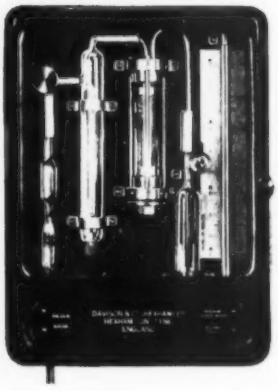

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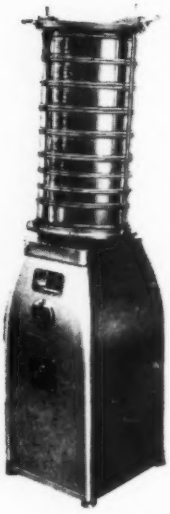

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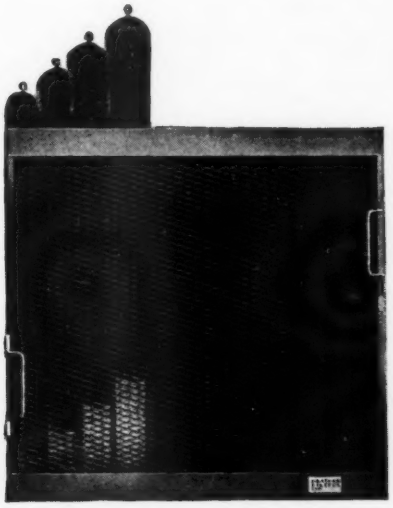

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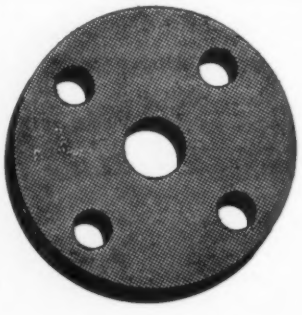

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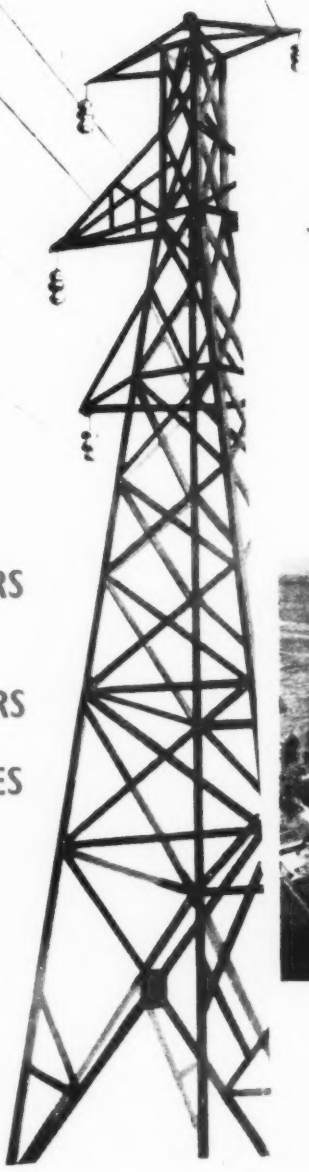

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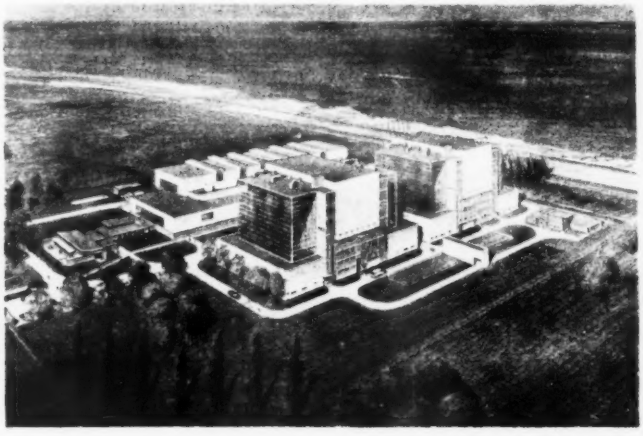

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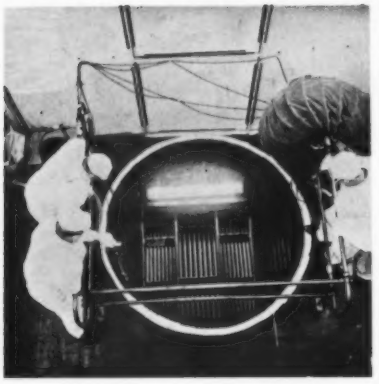

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